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Instructor's Guide for Vehicle Emissions Control Training

Colorado State Univ., Fort Collins

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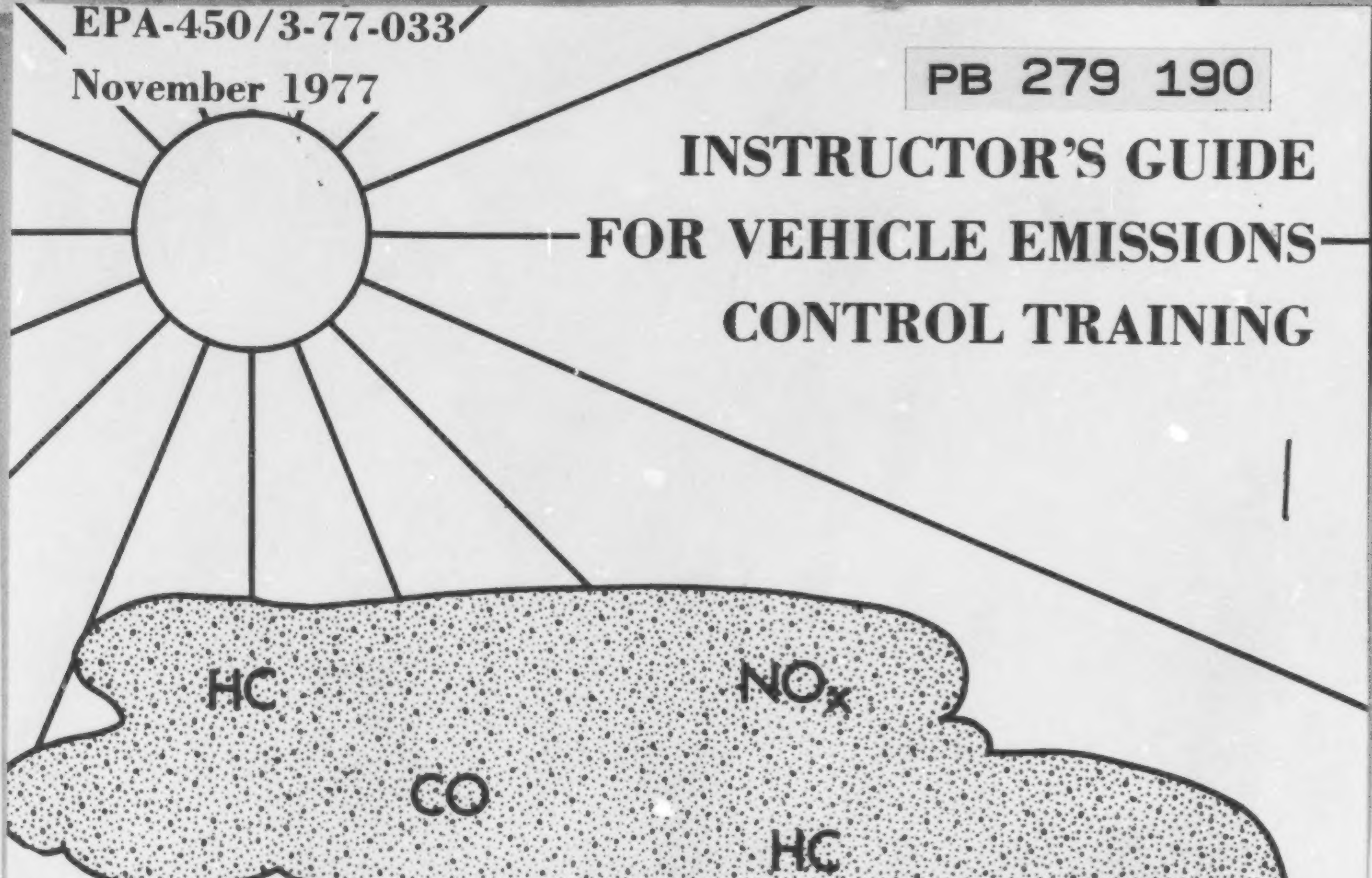
INSTRUCTOR'S GUIDE FOR VEHICLE EMISSIONS CONTROL TRAINING



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B.D. Hayes R.A. Ragazzi
M.T. Maness

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It is the intent of this book to explain each basic emissions control system and some of the more common devices found on today's car. Since it is an instructor's book it is designed to allow the instructor or facilitator to lead a group of students through the key points of each emissions control system.

Each basic emissions control system presented has the following information provided:

Part Identification
System Operation
System Control
System Effects on HC-CO and Driveability
Worksheets

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by

B.D. Hayes, Project Director
M.T. Maness, Associate Project Director
R.A. Ragazzi, Principal Investigator

Department of Industrial Sciences
Colorado State University
Fort Collins, Colorado 80523

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EPA Project Officer: Bruce Hogarth

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Foreword

Motor vehicle emissions control is becoming an increasingly large part of each person's life who is associated with the automotive industry. This is particularly true of the people that have to service today's motor vehicles. Since the beginning of motor vehicle emissions control in the mid-1960's, a number of different emissions control systems have evolved. These systems have been augmented with a variety of other devices that only add to the cluttered and confusing array of wires, plumbing and vacuum hoses that are found under the hood of most cars today. It is of little wonder that a large number of service people feel intimidated and confused when they look under the hood of today's cars.

It is the intent of this book and the student workbook to explain each basic emissions control system and some of the more common devices found on today's cars. Each discussion and exercise will be concerned with the basic concept (what does the system do?) of a certain system. If a service technician can understand the concept of a system and how it relates to driveability and emissions, he is on the right road for increasing profits, satisfying customers, and aiding in the effort toward clean air.

Another advantage to learning the concepts of emissions control systems is that, the same system concept applies to nearly every car. This reduces some of the confusion that results from studying Ford's system today, AM's system tomorrow and Chrysler's the day after. Once a concept is understood that knowledge can be applied to nearly all cars. The hardware may be somewhat different in appearance, but the job it is performing is essentially the same.

We hope these booklets will help remove some confusion and aid the mechanic in the performance of his job.

ACKNOWLEDGMENTS

The Motor Vehicle Emissions Control Staff of the Department of Industrial Sciences at Colorado State University would like to acknowledge the efforts extended by the Environmental Protection Agency, Research Triangle Park, for their contributions to the development of this booklet.

A special thanks must be extended to the automotive vehicle equipment and parts manufacturers for their cooperation and assistance in the development of this training material.

Instructor's Guide Book

The Instructor's Book is designed to allow the instructor or facilitator to lead a group of students through the key points of each emissions control system. — The following topics are discussed:

Each basic emissions control system presented will have the following information provided.

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PART IDENTIFICATION

The basic parts of each emissions control system will be identified. Physical identification of each part involved in a system is important. The identification of parts related to a specific system allows a person to look under the hood of a car and "see" systems, rather than a confusing mass of hoses, switches, and other devices. A very brief description of what the part does is also provided.

SYSTEM OPERATION

In this section the individual parts of each system are explained. The total system is studied from a functional viewpoint which tells what it is supposed to do. The way the system operates is explained, showing flow paths, and variations due to different modes of engine operation. Understanding how a system operates makes troubleshooting and correcting problems a much simpler task.

SYSTEM CONTROL

This section deals with the control of a system. Many emissions control systems are controlled by various temperature devices and/or sources of engine vacuum. This section will deal with how a particular system is or may be controlled. Understanding of this portion also enhances the troubleshooting ability of the service technician.

SYSTEM EFFECTS ON HC-CO AND DRIVEABILITY

This section deals with the effect of the system on emissions and driveability. It explains how and why the system affects emissions and driveability. It is hoped this section will build an appreciation of the need for proper operation and adjustment of any system that affects the internal combustion engine.

WORKSHEETS

For each system a basic worksheet is included. The purpose of this worksheet is to enforce the previously covered material. The use of hands-on and the effects that establishing different system conditions have on emissions are extremely important tools in the learning process. Incorporated with the worksheets are quick operational checks that can be made on each system.

Cont from PSV

CONTENTS

Unit 1 - Cause and Effect 1
  Hydrocarbons 1
  Carbon Monoxide 2
  Oxides of Nitrogen 2
Unit 2 - Infrared Exhaust Gas Analyzer 5
  Parts of Analyzer 5
  Causes for various HC-CO Meter Readings 6
  Worksheet 11
Unit 3 - Ignition and Carburetion 13
  Idle Mixture Adjustments - CO Emissions 13
  Idle Mixture Adjustments - HC Emissions 14
  Advancing Ignition Timing - HC Emissions 14
  Worksheet 16
Unit 4 - Positive Crankcase Ventilation 17
  Crankcase 18
  Ventilation 18
  Closed PCV System 18
  Flow of Blowby Gases 19
  Purpose of PCV Valve 20
  Control of HC, CO and Driveability 21
  Operational Checks 23
  Testing 25
  Worksheet 25
Unit 5 - Thermostatic Air Cleaners 27
  Types of TAC Systems 27
  Parts Common to TAC Systems 28
  Major Parts of Thermostatic Type 28
  Major Parts of Vacuum Motor Type 29
  Operating Modes Common to TAC Systems 29
  Operation and Control of Thermostatic Type 31
  Operation and Control of Vacuum Motor Type 32
  Emissions and Driveability 35

cont from pg vii

Operational Checks 36
Worksheet 39

Unit 6 - Air Injection Systems 41
Main Components 41
Air Flow 42
Diverter Valve Operation 43
Pressure Buildup Diverter Valve 44
Purpose of Air Switching Valve 44
Gulp Valve 45
Control of HC, CO and Driveability 46
Operational Checks 47
Worksheet 50

Unit 7 - Fuel Evaporation Control 51
Components of System 51
Operation of System 53
Methods to Purge Fuel Vapors 55
Operation of Carburetor Fuel Bowl Vents 57
Control of HC, CO and Driveability 57
Maintenance Checks 58
Worksheet 59

Unit 8 - Exhaust Gas Recirculation 61
Purpose of EGR Valve 61
Control Components 62
Ported Vacuum EGR with CTO Switch 63
Venturi Vacuum EGR with CTO Switch 64
Ported Vacuum EGR with Back Pressure Sensor 65
Control of HC, CO, NO_x and Driveability. 66
Operational Checks 68
Worksheet 72

Unit 9 - Spark Control Systems 73
Purpose for Retarted Spark Timing at Idle 73
Parts of Transmissions Control Spark System 73
Operation of Transmissions Controlled Spark System 74

con't from P8 unit

Transmission Controlled Spark System with CTO Switch 75

Transmission Controlled Spark System with Hot and Cold Temperature Switch 76

OSAC Valve 78

Control of HC, CO, NO_x and Driveability 79

Operational Checks 80

Worksheet 83

Unit 10 - Catalytic Converter Systems 85

Purpose of Catalytic Converter 85

Construction of Converter 86

Engine Performance Effects Catalytic Converter Operation 86

Purpose of Protection Systems 87

Operation of Protection Systems 88

Purpose of Exhaust System Heat Shield 90

Use of Unleaded Fuel 90

Control of HC, CO, NO_x and driveability 90

Worksheet 92

UNIT 1

CAUSE AND EFFECT

- BACKGROUND INFORMATION -

Throughout this course of study, the terms, Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen will be used frequently. These are terms that should be understood by today's service technician. These terms appear in all information relating to emissions control. They appear on the majority of VEHICLE EMISSIONS CONTROL INFORMATION labels found under the hood of today's cars. A service technician must understand these terms if he is to properly adjust today's automobiles, and properly use today's test equipment. Knowledge of these terms also aids the technician in giving explanations to customer-related questions.

A. Discuss Hydrocarbons.

Hydrocarbons, abbreviated HC, are the chemical components that make up all petroleum products. This includes gasoline, fuel oil, and lubricating oil. In regard to today's cars, hydrocarbon (HC) emissions indicate gasoline that did not burn. This may be expressed as unburned hydrocarbon emissions.

This meter shows us how much unburned gasoline (HC) is leaving the engine and being exhausted to the air.

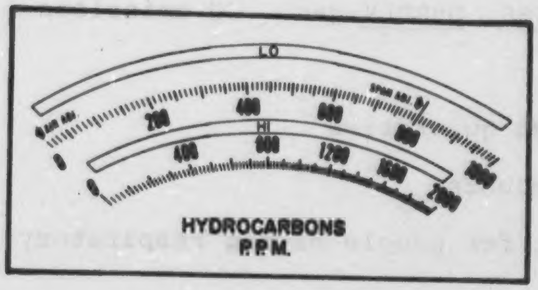

Figure 1-1

Hydrocarbon emissions contribute to the following conditions.

1. The formation of photochemical smog.
2. Eye irritation
3. Health hazards - some unburned hydrocarbons are suspected of causing cancer and other health related problems.

B. Discuss Carbon Monoxide.

Carbon Monoxide (CO) results from incomplete combustion. In order to burn a given amount of gasoline completely, a certain amount of air must be present. If there is too much fuel present for the amount of air, carbon monoxide (CO) emissions increase. As the proper amount of air becomes available for a certain amount of fuel - CO emissions decrease.

This meter shows us how closely the carburetor is adjusted. Low CO - close to proper air/fuel ratio. High CO - rich mixture; too much fuel, not enough air.

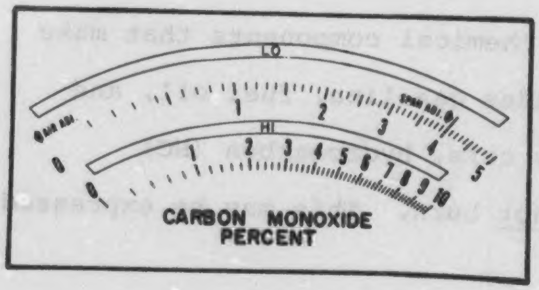

Figure 1-2

Carbon Monoxide is a colorless, ODORLESS, DEADLY gas. CO emissions can cause

1. Death - if inhaled in large enough quantities
2. Headaches and nausea in lesser amounts
3. Increased difficulty in breathing for people having respiratory problems.

C. Discuss Oxides of Nitrogen.

Oxides of nitrogen (NO_x) result from the combustion or burning process in the engine. Seventy-eight (78%) percent of the air we breathe is made up of nitrogen. When this air is drawn into the engine and burned at temperatures greater than approximately 2500°F, NO_x or oxides of nitrogen are formed.

> Instruments are available that read NO_x emissions. Because of their high cost, they are not usually found in automobile service facilities.

Oxides of nitrogen (NO_x) emissions contribute to the following conditions.

1. NO_x + sunshine and hydrocarbons form photochemical smog.
2. NO_x contributes to the dirty brown color associated with photochemical smog.
3. Ozone (O_3) results from chemical reactions involving NO_x.
    - a) Ozone contributes to the smell associated with photochemical smog.
    - b) Ozone also acts as an irritant to the eyes and lungs.
    - c) Ozone causes rubber products to rapidly deteriorate and is harmful to many types of plants.

UNIT 2

INFRARED EXHAUST GAS ANALYZER

-BACKGROUND INFORMATION-

The infrared exhaust gas analyzer is a piece of test equipment used to measure hydrocarbons and carbon monoxide. The infrared unit provides a hydrocarbon reading in parts per million (PPM). (One (1) part per million is equivalent to 1 second in 11.5 days.) Carbon monoxide readings are given in percent (%). Normally the hydrocarbon meter and the carbon monoxide meter have two scales -- a high scale and a low scale. Either scale can be selected by pressing the appropriate button or shifting a selector switch. The infrared analyzer can provide much valuable information for diagnostic work. However, to utilize the infrared in this manner requires an understanding of hydrocarbons (HC) and carbon monoxide (CO). Hydrocarbons are unburned fuel. There is always a small portion of gasoline that does not burn. The hydrocarbon meter shows how much unburned fuel is being exhausted. Carbon monoxide is a product of incomplete burning. If too much fuel is present for the amount of air present, the CO meter will show a large amount of carbon monoxide being exhausted to atmosphere. Understanding HC and CO and continued use of the infrared exhaust gas analyzer together with an oscilloscope can greatly increase diagnostic capabilities.

A. Explain the basic parts of an infrared exhaust gas analyzer.

1. Infrared Heater - Provides a constant source of infrared waves or energy through the reference and sample cells.
2. Chopper Wheel - A segmented disc driven by a motor. The disc

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constantly interrupts the infrared signal. This provides a pulsating infrared signal.

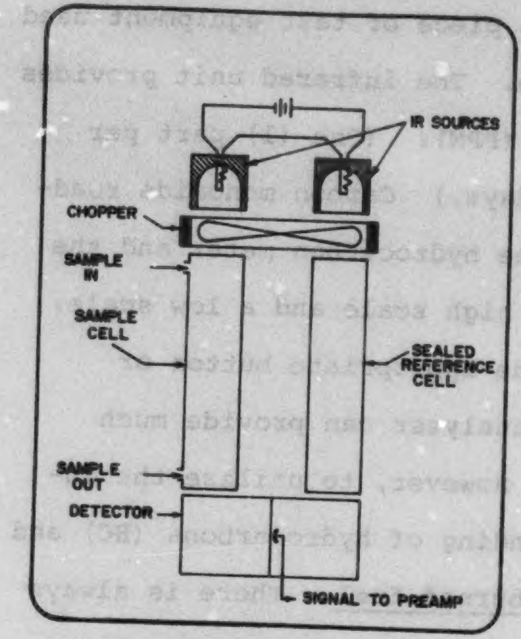
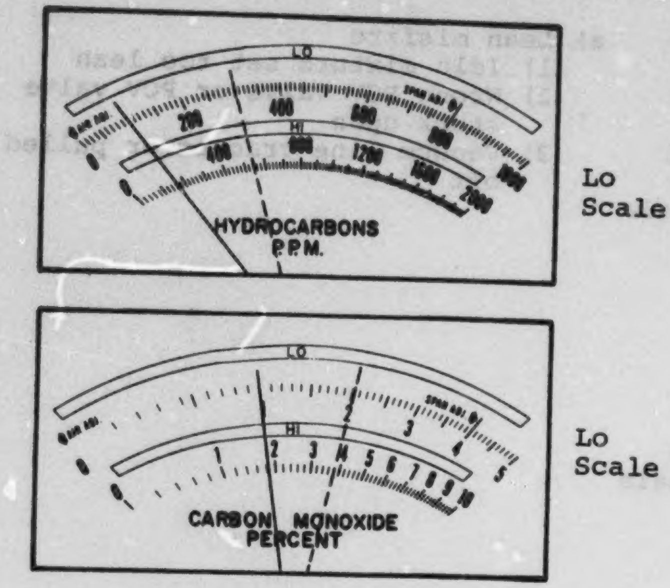

IR SOURCES
CHOPPER
SAMPLE IN
SAMPLE CELL
SEALED REFERENCE CELL
SAMPLE OUT
DETECTOR
SIGNAL TO PREAMP

Figure 2-1

3. Sample Cell - A cell that the exhaust gases flow through. Infrared or energy is absorbed by the HC and CO as they pass through the sample cell.
4. Reference Cell - A cell that contains no HC or CO. No infrared waves or energy is absorbed in this cell.
5. Detector - Changes the infrared signals from the filters to an electrical signal.
6. Amplifier - Increases the electrical signal from the detector to provide meter readings.

B. Explain some of the possible causes for the following HC-CO meter readings.

NOTE: All readings must be taken with the engine at operating temperature. ZERO and SPAN analyzer following manufacturer's procedure.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CARBON MONOXIDE
PERCENT
Lo Scale

Figure 2-2

1. With the engine at operating temperature and idling, Figure 2-1 shows a "normal" reading.

   NOTE: "Normal" readings vary from car to car. The normal readings shown here do not apply to catalytic converter equipped cars.

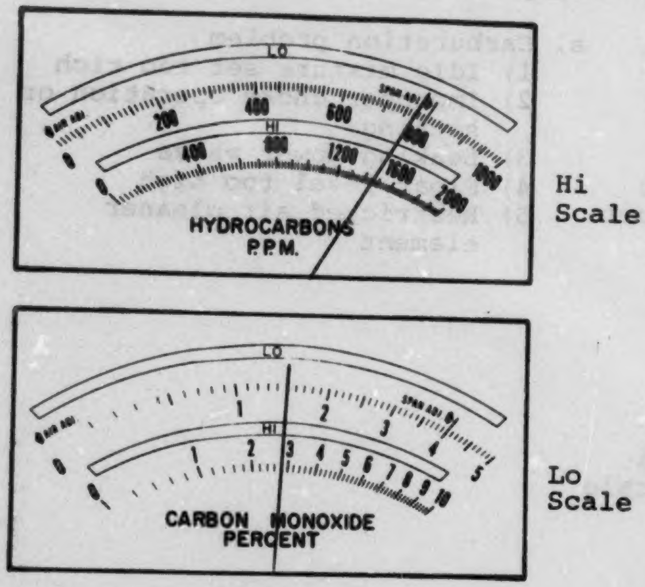
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Figure 2-3

2. Symptoms - Rough idle. Possible causes:

   a) Ignition System Problem
      1) Timing too far advanced
      2) Fouled or shorted spark plug
      3) Open or grounded spark plug wire
      4) Crossed spark plug wires
      5) Leaking valves
      6) Leaking EGR valve
      7) Primary ignition system problem

NOTES:

3. Symptoms - Rough idle

a) Lean misfire
  1) Idle mixture set too lean
  2) Wrong PCV valve or PCV valve stuck open
  3) Vacuum line cracked or pulled off

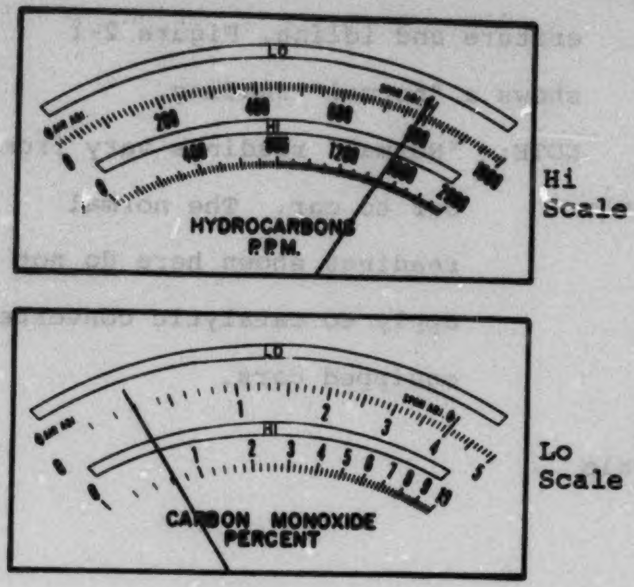
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Figure 2-4

4. Symptoms - Rough idle

a) Carburetion problem
  1) Idle mixture set too rich
  2) Improper choke operation or setting
  3) Leaking power valve
  4) Float level too high
  5) Restricted air cleaner element

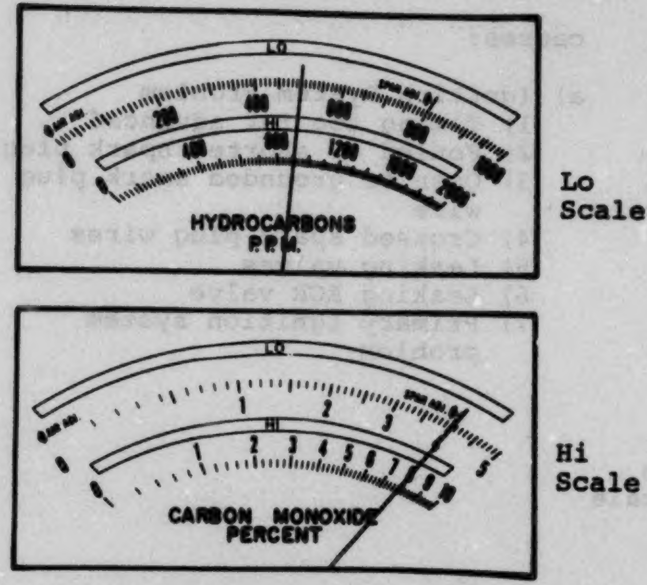
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Figure 2-5

NOTES:

5. No rough idle

a) Air injection system not working

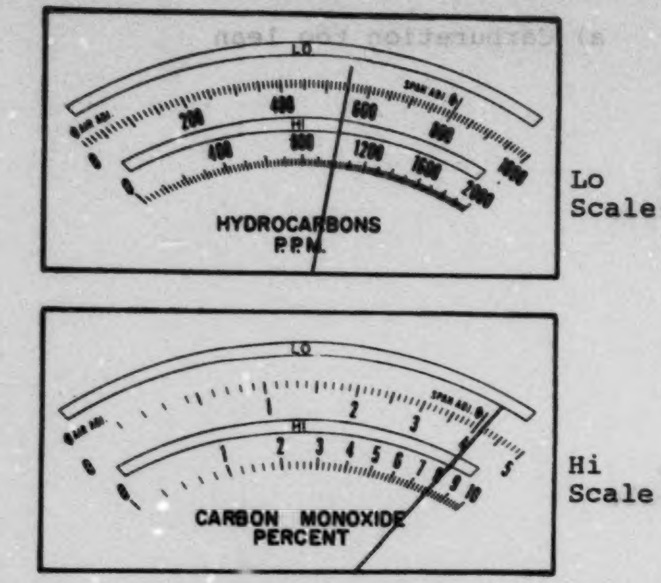
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Figure 2-6

6. Symptoms - Engine surging, 1500 rpm

a) Erratic EGR valve operation

b) Timing too far advanced

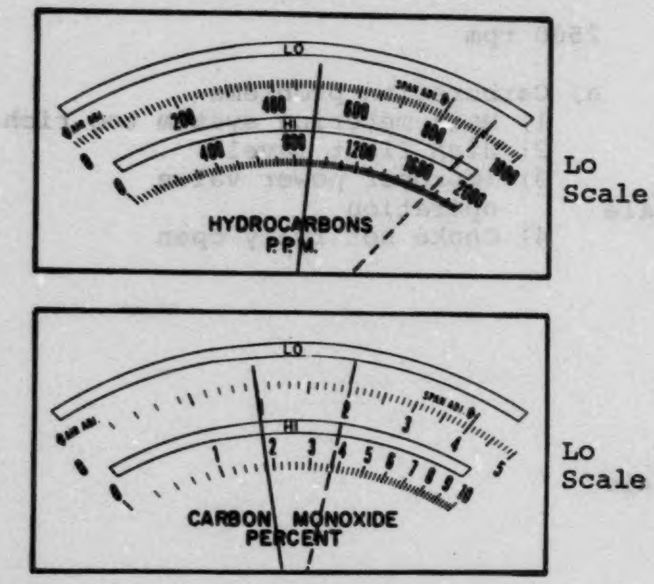
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Figure 2-7

NOTES:

7. Symptoms - Engine surging, 1500 rpm

   a) Carburetion too lean

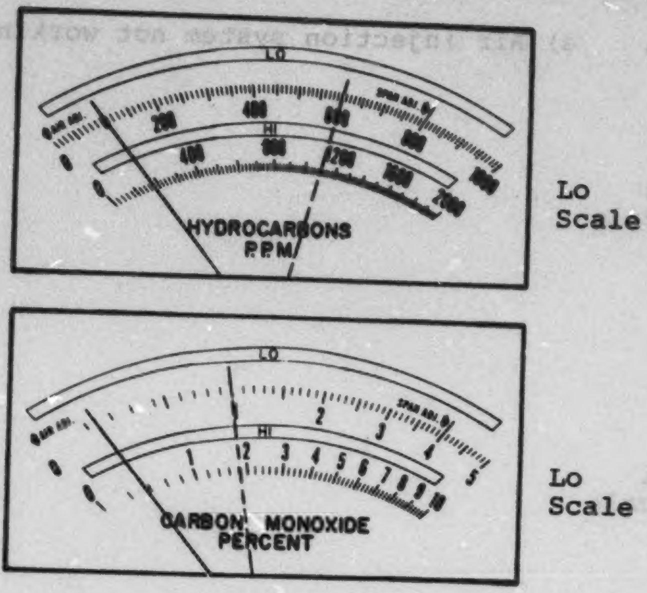
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Figure 2-8

8. Symptoms - Possible black smoke,

   2500 rpm

   a) Carburetion problems
      1) Main metering system too rich
      2) High float level
      3) Improper power valve operation
      4) Choke not fully open

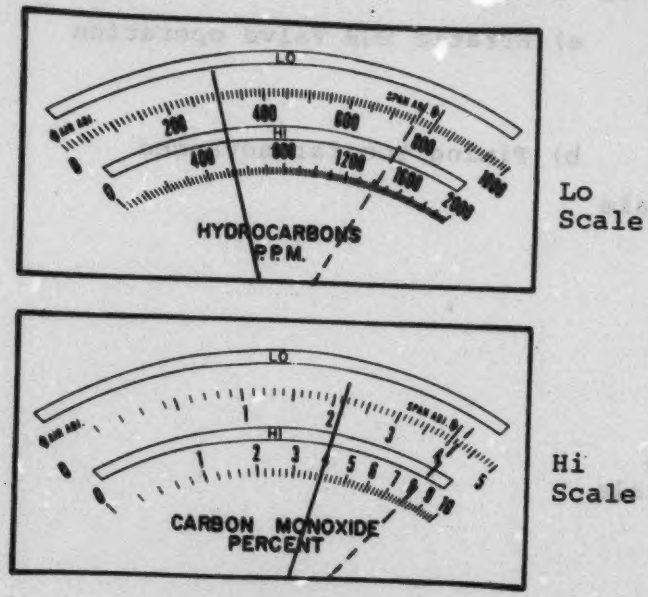
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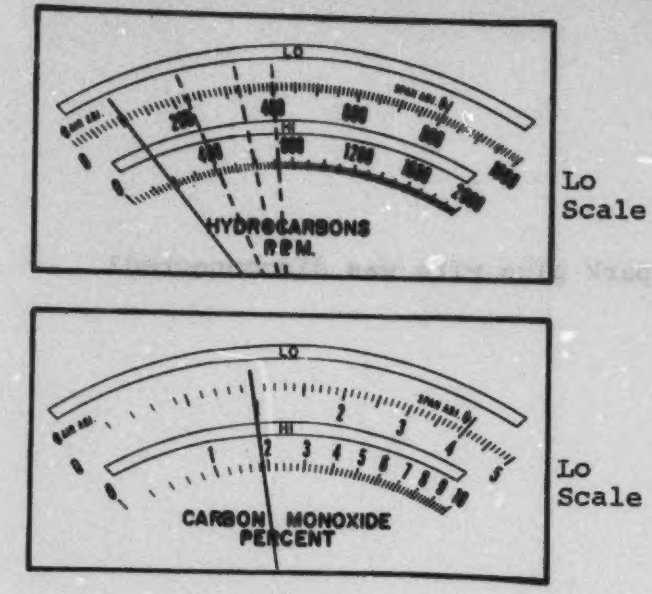
Figure 2-9

9. Symptoms - Occasional miss, 1500-2500 rpm.

a) Occasional ignition misfire

b) Sticking valve(s)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CARBON MONOXIDE
PERCENT
Lo Scale

Figure 2-10

Have your students fill out the following worksheet in the student workbook.

Engine Speed	Worksheet Test Conditions	HC (PPM)	CO (%)
0	Warm up - Zero and Span Analyzer	--	--
0	Remove gas cap. Hold probe next to filler neck. Which meter indicates unburned gasoline?		
Idle	Record HC and CO for reference reading.		
Idle	Remove and ground one spark plug wire.		
Idle	Remove air cleaner unit.		
Idle	Partially close choke.		

1. Why did CO decrease when one spark plug wire was disconnected?

2. Why did HC increase when one spark plug wire was disconnected?

UNIT 3

IGNITION AND CARBURETION

- BACKGROUND INFORMATION -

Adjusting basic ignition timing and carburetor idle mixture screws has always been a part of a tuneup. Since the introduction of motor vehicle emissions controls, these basic adjustments have become critical. Timing and carburetor idle adjustment are a major part of effective vehicle emissions control. It is interesting to note that approximately 80% of the cars that fail an idle emissions check can be corrected by PROPERLY adjusting ignition timing and idle mixture. It is possible to achieve an acceptable idle quality and decent performance and still keep hydrocarbon and carbon monoxide levels low.

A. Explain how carburetor idle mixture adjustments affect CO emissions.

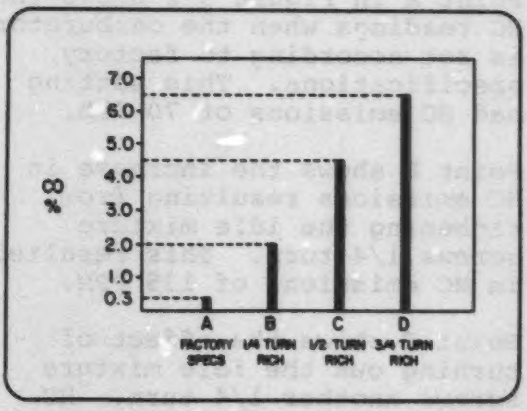

Figure 3-1

Idle mixture screws adjustments

1. CO emissions are directly related to the air/fuel ratio which at idle is controlled by the idle mixture adjustment screws.
    a) Point A in Figure 3-1 shows a recommended factory idle mixture setting. This setting had CO emissions of .3%.
    b) Point B shows the increase in CO emissions resulting from richening the idle mixture adjustment screws 1/4 turn. This resulted in CO emissions of 2%.
    c) Point C shows the effect of turning out the idle mixture screws another 1/4 turn. CO emissions jumped to 4.6%.
    d) Another 1/4 turn rich is shown at point D. This increased CO emissions to 6.5%.

e) 1% CO equals 10,000 parts per million of CO. Turning the idle mixture adjusting screws out only 3/4 of a turn from factory specifications increased CO emissions from 3,000 ppm to 65,000 ppm.

Emphasize the importance of setting the idle mixture screws and idle speed adjustments according to the manufacturer's recommended procedure.

B. Explain how carburetor idle mixture screw adjustments affect HC emissions.

1. The richer the idle adjustment, the less air or oxygen there is for combustion. Rich mixtures increase the amount of unburned fuel HC as well as CO

    a) Point A in Figure 3-2 shows the HC readings when the carburetor is set according to factory specifications. This setting had HC emissions of 70 PPM.

    b) Point B shows the increase in HC emissions resulting from richening the idle mixture screws 1/4 turn. This resulted in HC emissions of 135 PPM.

    c) Point C shows the effect of turning out the idle mixture screws another 1/4 turn. HC emissions reached 195 PPM.

    d) Another 1/4 turn rich is indicated at point D. This increased HC emissions to 250 PPM.

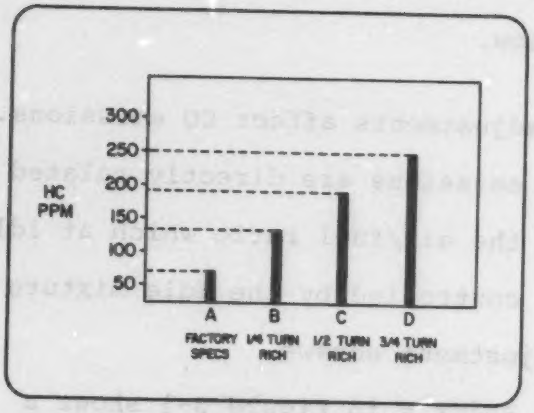

Figure 3-2

Idle Mixture Screws Adjustment

C. Explain why advancing ignition timing increases HC emissions.

1. The more ignition timing is advanced, the cooler the cylinder

walls and exhaust system become. Decreasing cylinder wall and exhaust temperatures does not allow extra burning to occur in these areas. The result is increased HC emissions.

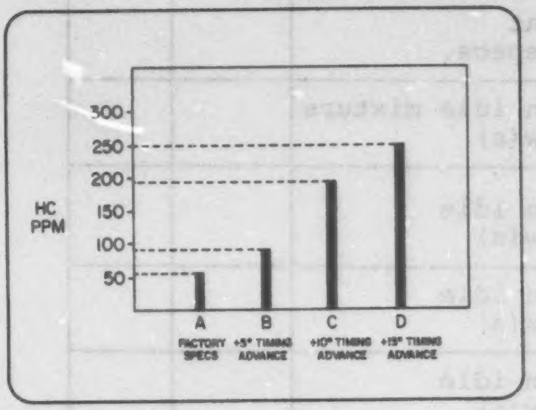

Figure 3-3

Ignition Timing

a) Point A in Figure 3-3 shows the HC emissions when timing is set to factory specs. HC emissions were 60 PPM.

b) Point B shows the increase in HC emissions from advancing timing 5° over factory specs. HC emissions increased to 90 PPM

c) Point C shows the effect another 5° advance in timing for a total of 10°. HC emissions increased to 190 PPM.

d) Point D represents another 5° advance in initial timing for a total of 15°. This increased HC emissions to 250 PPM.

Emphasize the importance of setting ignition timing to factory specifications. Remember as timing is advanced, the engine speed increases. This requires a smaller throttle plate opening. The smaller throttle plate opening makes it difficult to achieve the proper air/fuel ratio at idle.

NOTE: The readings shown in Figures 3-1, 3-2 and 3-3 are representative. Some vehicles show larger increases in emissions levels while others show less of an increase.

Have your students fill out the following worksheet in the student workbook as they perform the tests.

Engine Speed	Test Conditions	HC (PPM)	CO (%)
Idle (manufacturer's specs.)	Carburetor set at manufacturer's specs.		
Idle - maintain manufacturer's recommended idle speed	1/4 turn rich on idle mixture adjustment screw(s)		
	1/4 turn rich on idle adjustment screw(s)		
	1/4 turn rich on idle adjustment screw(s)		
	1/4 turn rich on idle adjustment screw(s)		
	Reset idle mixture adjustment screws to manufacturer's specs		
Idle - maintain manufacturer's recommended idle speed	Timing set at manufacturer's specs		
	Advance timing 5°		
	Advance timing 5°		
	Advance timing 5°		
	Advance timing 5°		
	Reset timing to manufacturer's specs		

UNIT 4

POSITIVE CRANKCASE VENTILATION (PCV)

- BACKGROUND INFORMATION -

Unburned hydrocarbons (HC) make up a large portion of the blowby gases that enter the engine crankcase. These blowby gases are forced past the piston rings on the compression and power stroke. As far back as the 1920's, it was known that these gases, namely unburned hydrocarbons, water vapor and other products of combustion, were hazardous to an engine's longevity. Blowby gases, if left in the crankcase, caused rusting, corrosion, oil dilution and the formation of sludge. The road draft tube was used for many years to ventilate the engine crankcase. This method allowed the blowby gases, which contain unburned hydrocarbons, to be discharged to the atmosphere. The positive crankcase ventilating systems began appearing in the 1960's with the advent of motor vehicle emissions control. The positive crankcase ventilating system does not discharge blowby gases back to the atmosphere. With this system blowby gases are drawn back into the engine and burned. This allows ventilation of the crankcase and provides 100% control over this source of unburned hydrocarbons.

A. Explain what areas of the engine are part of the crankcase. This can be defined as: any area inside the engine where oil is not under pressure. This includes the following areas:

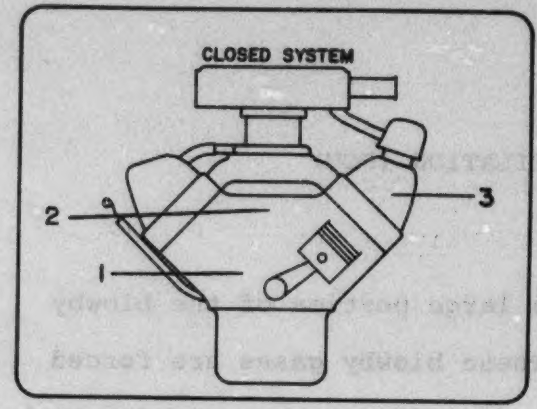

Figure 4-1

1. The area above the oil level in the oil pan, i.e., crankshaft area connecting rod area.
2. The area where the valve lifters and push rods are located.
3. The area under the valve cover(s) where the rocker arms and upper part of the valve train are located.

B. Explain what is meant by the term "Ventilation."

Ventilation as applied to the engine crankcase, means that the blowby gases must be drawn out and fresh air drawn in. By constantly removing blowby gases, the following problems are kept to a minimum.

1. Rusting of internal engine parts - caused by water vapor.
2. Corrosion of internal engine parts - caused by acids that form from different gases in the blowby gas.
3. Oil dilution - caused by unburned fuel or hydrocarbons - causes excessive engine wear due to poor lubrication.
4. Formation of engine deposits - can cause very hard deposits that stick piston rings, valves, hydraulic lifters. Sludge is also formed and can block oil pump pickup screens and prevent proper lubrication.

C. Explain the main components of the "Closed" PCV system.

The closed PCV system has been standard equipment on the majority of cars built since 1968.

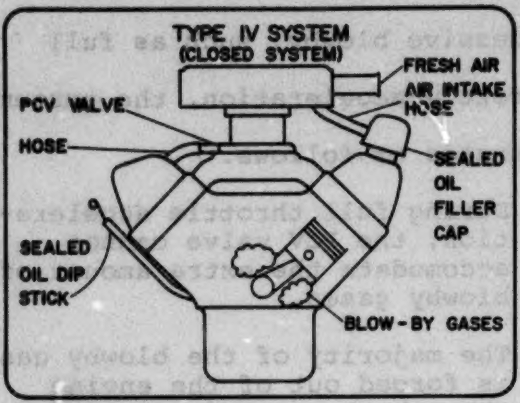
TYPE IV SYSTEM
(CLOSED SYSTEM)
FRESH AIR
AIR INTAKE HOSE
PCV VALVE
HOSE
SEALED OIL FILLER CAP
SEALED OIL DIP STICK
BLOW-BY GASES

Figure 4-2

1. **Sealed Oil Filler Cap** - to prevent the escape of blowby gases to the atmosphere during heavy acceleration.
2. **Air Intake Hose** - allows fresh air to enter the engine crankcase from the air cleaner.
3. **PCV Valve** - meters the flow of blowby gases from the crankcase back to the intake manifold for reburning.
4. **Sealed Oil Dipstick** - prevents the escape of blowby gases to atmosphere and aids in sealing the crankcase.

D. Explain the flow of blowby gases in the closed PCV system.

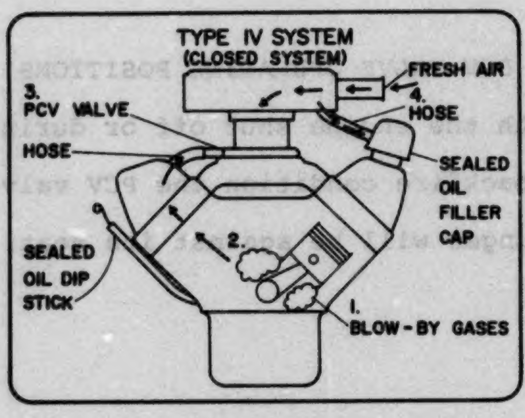
TYPE IV SYSTEM
(CLOSED SYSTEM)
FRESH AIR
3.
PCV VALVE
4.
HOSE
HOSE
SEALED OIL FILLER CAP
2.
SEALED OIL DIP STICK
1.
BLOW-BY GASES

Figure 4-3

1. Blowby enters the crankcase by escaping past the piston rings.
2. Intake manifold pressure is normally much less than the pressure in the crankcase. This difference in pressure causes the blowby gases to be drawn into the intake manifold.
3. The amount of blowby gas that is drawn into the intake manifold is controlled by the PCV valve.
4. Fresh air is drawn into the

crankcase through the air cleaner and intake hose.

5. This is normal operation of the system. During conditions of excessive blowby, such as full throttle acceleration, the system operates as follows.

   a) During full throttle acceleration, the PCV valve cannot accomodate the extra amount of blowby gases.

   b) The majority of the blowby gas is forced out of the engine through the sealed oil filler cap and air intake base into the air cleaner. From inside the air cleaner, the blowby gases are drawn down through the carburetor into the engine to be burned.

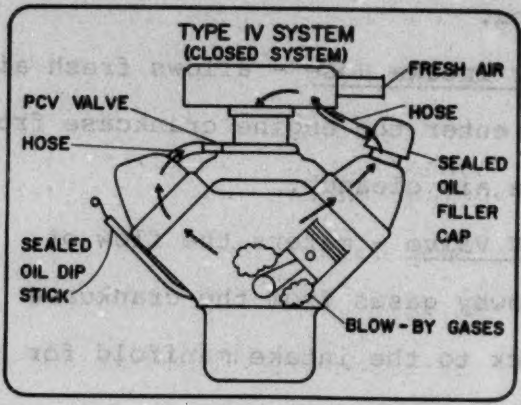
TYPE IV SYSTEM
(CLOSED SYSTEM)
FRESH AIR
PCV VALVE
HOSE
HOSE
SEALED OIL FILLER CAP
SEALED OIL DIP STICK
BLOW-BY GASES

Figure 4-4

E. Explain the purpose of the PCV valve.

The PCV valve provides a metered opening that varies in size to correspond to varying engine operating conditions and varying amounts of blowby gases.

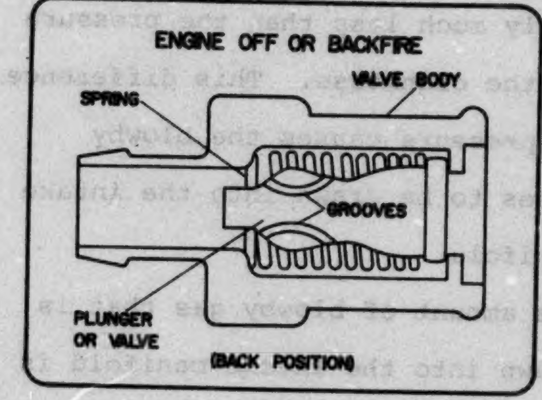
ENGINE OFF OR BACKFIRE
VALVE BODY
SPRING
GROOVES
PLUNGER OR VALVE
(BACK POSITION)

Figure 4-5

PCV VALVE OPERATING POSITIONS

1. With the engine shut off or during a backfire condition the PCV valve plunger will be against its seat.

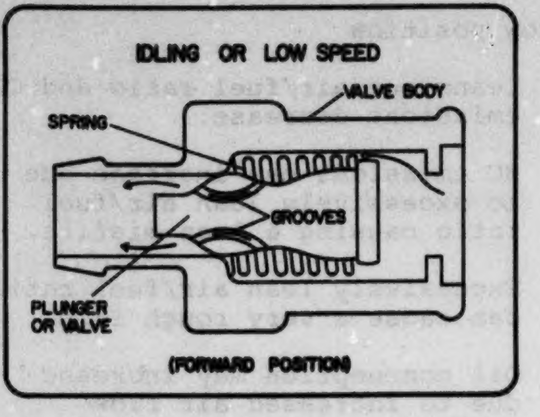
IDLING OR LOW SPEED
VALVE BODY
SPRING
GROOVES
PLUNGER OR VALVE
(FORWARD POSITION)

Figure 4-6

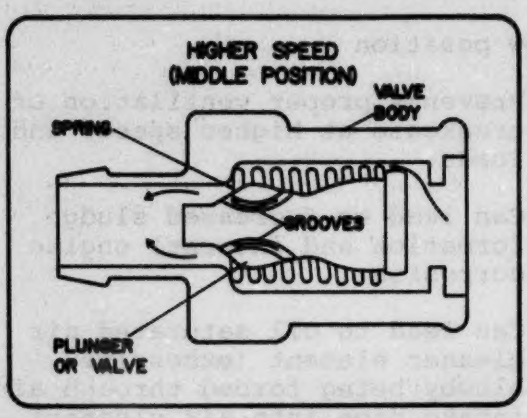
HIGHER SPEED (MIDDLE POSITION)
VALVE BODY
SPRING
GROOVES
PLUNGER OR VALVE

Figure 4-7

2. During periods of engine idling or low cruise the following conditions are present.
   a) Normally only a small amount of blowby during these engine conditions.
   b) Intake manifold vacuum high.
   c) Plunger is pulled against spring tension, off its seat.
   d) Blowby gases are metered through grooves to the intake manifold..
3. As engine speed and load increase, the following engine conditions are present:
   a) Blowby increases as the engine load increases.
   b) Less manifold vacuum allows the spring to push the plunger back toward its seat.
   c) In this position there is more area for the larger amount of blowby gases to pass through.

F. Explain how the PCV system can affect HC and CO emissions and driveability.

Since the PCV system draws unburned hydrocarbons and air into the intake manifold it does affect the air/fuel ratio. This in turn affects the HC and CO emissions as well as vehicle driveability.

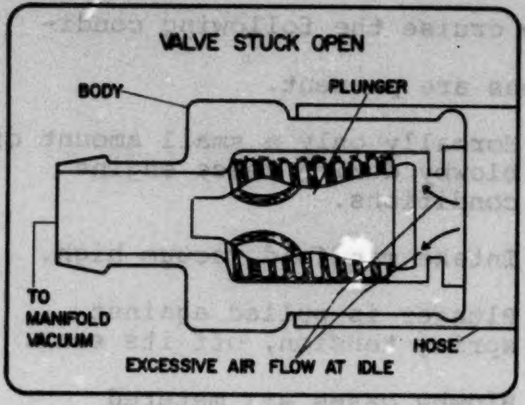
VALVE STUCK OPEN
BODY
PLUNGER
TO MANIFOLD VACUUM
HOSE
EXCESSIVE AIR FLOW AT IDLE

Figure 4-8

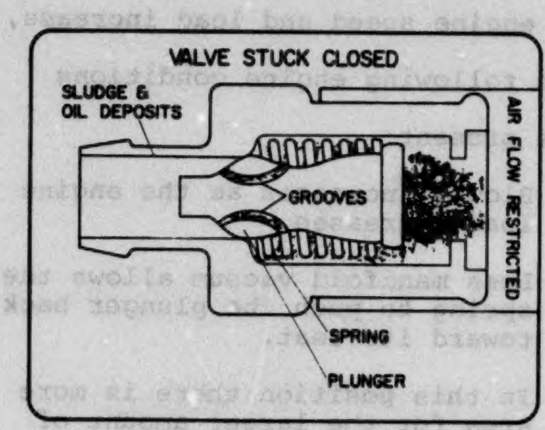
VALVE STUCK CLOSED
SLUDGE & OIL DEPOSITS
GROOVES
AIR FLOW RESTRICTED
SPRING
PLUNGER

Figure 4-9

1. PCV valve stuck in the maximum flow position
   a) Leans out air/fuel ratio and CO emissions decrease.
   b) HC emissions may increase due to excessively lean air/fuel ratio causing a lean misfire.
   c) Excessively lean air/fuel ratio can cause a very rough idle.
   d) Oil consumption may increase due to increased air flow through crankcase.
2. PCV valve stuck in the minimum flow position
   a) Prevents proper ventilation of crankcase at higher speeds and loads.
   b) Can lead to increased sludge formation and internal engine corrosion.
   c) Can lead to oil saturated air cleaner element (excessive blowby being forced through air intake pipe into air cleaner). An oil saturated air cleaner element can raise CO emissions.

Stress at this point the necessity for the proper PCV valve for a particular engine. The wrong PCV valve can cause any of the above problems.

G. At this time STRESS the following items.

1. Always check the manufacturer's service manual for:
   a) Specified mileage when suggested maintenance should be accomplished.
   b) Location of crankcase filters. There is normally a filter in the air intake line that runs from the valve cover to the air cleaner. This filter can be found in any of the following locations.
      1) in the air cleaner

2) in the oil filler cap
3) in the air intake line
4) inside the valve cover below the air intake line.

c) Some manufacturers specify different PCV valve part numbers at a certain number of miles. Be sure to replace the PCV valve with the proper one.

d) The suggested method for testing the PCV system.

H. PCV System Operational Checks.

The operational checks suggested here will indicate whether or not the crankcase is properly sealed and if the PCV system is working. It is possible for these operational tests to be passed with a wrong PCV valve. Therefore, insure the proper PCV valve is used in the system.

WHEN THESE CHECKS ARE PERFORMED, INSURE AREA IS WELL VENTILATED.

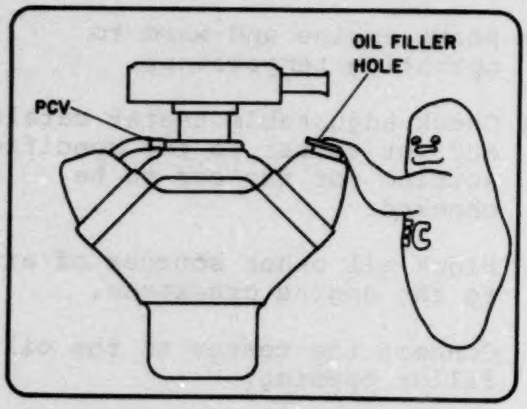

Figure 4-10

1. VACUUM DRAW TEST

a) Start engine and warm to operating temperature.

b) Remove oil filler cap and block all other sources of air to the crankcase.

c) Place a piece of paper over the oil filler hole.

d) After a short period of time the paper should be drawn down tightly by the vacuum created in the crankcase by the PCV system.

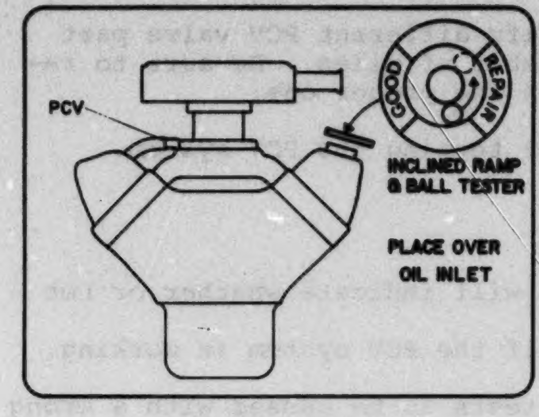

Figure 4-11

2. CRANKCASE VACUUM DRAW TEST USING THE INCLINED RAMP AND BALL TESTER.

a) Start engine and warm to operating temperature.

b) Remove oil filler cap and block all other sources of air to the crankcase.

c) Place the tester over the oil filler opening.

d) If crankcase vacuum is satisfactory the ball will move to the GREEN AREA.

e) If a pressure exists in the crankcase the ball will move into the RED AREA.

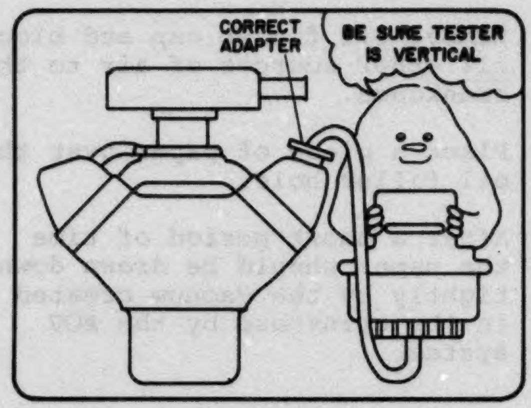

Figure 4-12

3. CRANKCASE VACUUM DRAW TEST USING THE ADJUSTABLE PCV SYSTEM TESTER.

a) Start engine and warm to operating temperature.

b) Check adjustable tester catalog and set tester to the specified setting for the car to be checked.

c) Block all other sources of air to the engine crankcase.

d) Connect the tester to the oil filler opening.

e) Hold tester in the upright (vertical) position.

f) If a green color shows in the slot the system is satisfactory.

g) If a yellow color shows in the slot it means the PCV system is marginal.

h) If a red color shows in the slot, this indicates a pressure in the crankcase.

NOTE: This tester can also be used to check the PCV valve operation.

I. Testing the PCV valve.

If any of the above checks did not show a vacuum in the crankcase, the PCV valve should be checked for proper operation.

1. CHECKING THE PCV VALVE.

a) Remove the PCV and shake it. If a rattle is heard, this only tells you the plunger is free. It is no indication of the physical condition of the plunger.

b) Start the engine.

c) Place your finger over the end of the PCV valve. You should feel a strong vacuum.

d) If no vacuum is felt, remove the PCV valve from the hose or intake manifold connection.

e) Check for vacuum at the end of the hose or manifold connection.

f) If no vacuum is felt, the hose or intake manifold passages are plugged and must be opened.

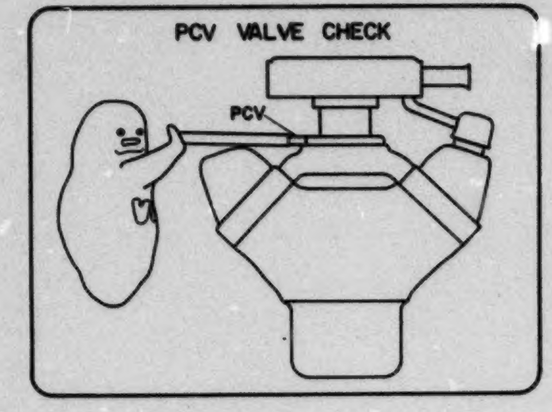

Figure 4-13

Have the students fill out the following worksheet in their student's workbook as they perform the tests.

Engine Speed	Test Condition	Pass	Fail
IDLE	VACUUM DRAW TEST Place sheet of paper over oil filler hole		
IDLE	VACUUM DRAW TEST Inclined Ramp and Ball		
IDLE	VACUUM DRAW TEST Adjustable Tester		
IDLE	PCV VALVE TEST		

UNIT 5

THERMOSTATIC AIR CLEANERS

- BACKGROUND INFORMATION -

Thermostatic air cleaners or heated air induction systems began appearing on automobiles in 1967. This system became necessary as carburetor air/fuel ratios became leaner. Leaner carburetor air/fuel ratios present a driveability problem when the engine is cold. Thermostatic air cleaners provide heated air to the carburetor. Heated air allows better fuel vaporization and more even fuel distribution; both of these factors provide better driveability and reduce HC and CO emissions. Thermostatic air cleaners are necessary with the shorter choke operation time used on newer vehicles. The use of preheated air also minimizes the problem of carburetor icing.

A. Explain that two different types of thermostatic air cleaner systems are used. Although two types are used both are sensitive to air temperature. The two types are:

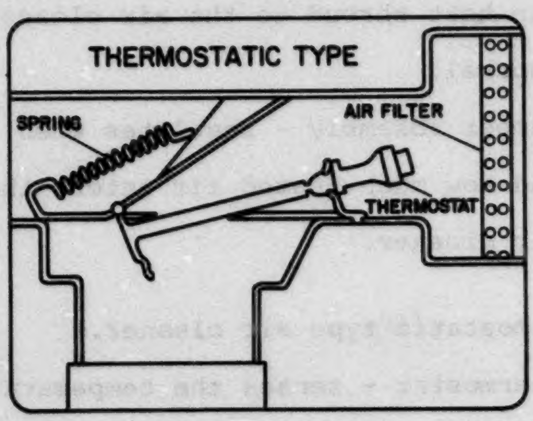

Figure 5-1

1. Thermostatic type

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2. Vacuum motor type

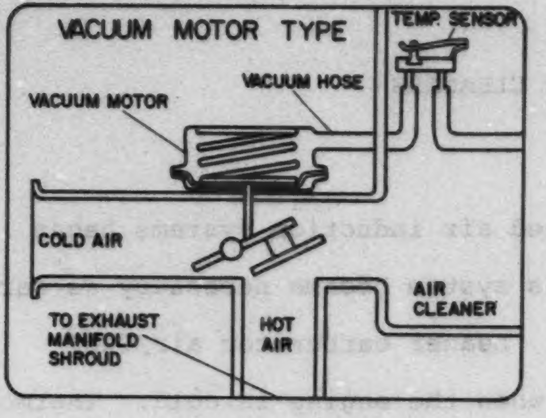
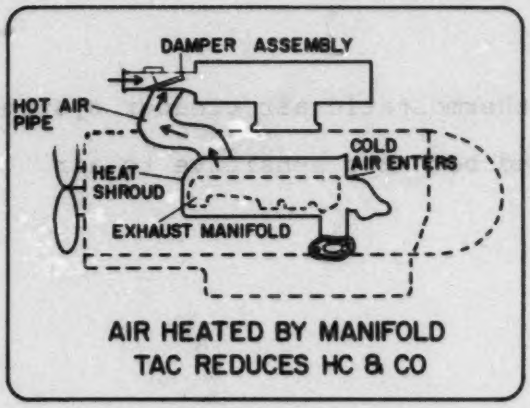

VACUUM MOTOR TYPE
TEMP. SENSOR
VACUUM HOSE
VACUUM MOTOR
COLD AIR
AIR CLEANER
TO EXHAUST MANIFOLD SHROUD
HOT AIR

Figure 5-2

B. Explain the parts that are common to both types of thermostatic air cleaner systems.


DAMPER ASSEMBLY
HOT AIR PIPE
COLD AIR ENTERS
HEAT SHROUD
EXHAUST MANIFOLD

AIR HEATED BY MANIFOLD
TAC REDUCES HC & CO

Figure 5-3

1. Exhaust manifold heat shroud - A piece of formed metal around the exhaust manifold that directs air flow over the exhaust manifold to preheat it.
2. Hot air pipe - directs the air from the heat shroud to the air cleaner snorkel.
3. Damper assembly - regulates when and how much heated air enters the air cleaner.

C. Identify the major parts of the thermostatic type air cleaner.

1. Thermostat - senses the temperature of the air entering the air cleaner and expands or contracts depending on temperatures.

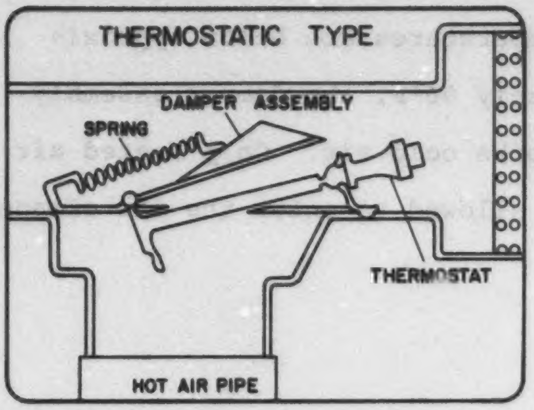

THERMOSTATIC TYPE
DAMPER ASSEMBLY
SPRING
THERMOSTAT
HOT AIR PIPE

Figure 5-4

2. Damper Assembly - regulated by the thermostat and spring to determine when and how much heated air enters the air cleaner.
3. Spring - aids the thermostat in the control of the damper assembly.

D. Identify the major parts of the vacuum motor type air cleaner.

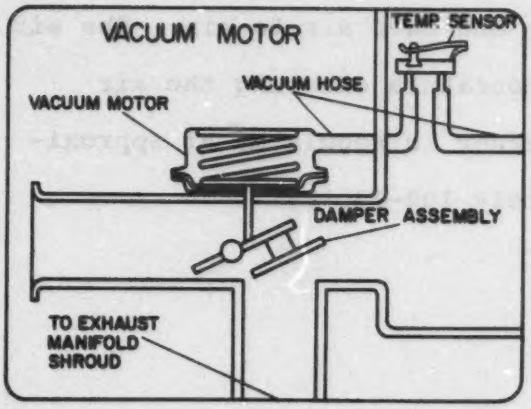

VACUUM MOTOR
TEMP. SENSOR
VACUUM HOSE
VACUUM MOTOR
DAMPER ASSEMBLY
TO EXHAUST MANIFOLD SHROUD

Figure 5-5

1. Vacuum motor - controlled by intake manifold vacuum to open or close the damper assembly.
2. Temperature sensor - senses the incoming air temperature and controls the amount of vacuum applied to vacuum motor.
3. Vacuum hose - connects vacuum motor to temperature sensor and a source of manifold vacuum.

E. Explain the three operating modes that are common to both types of air cleaner.

These three modes are common to both types of air cleaners.

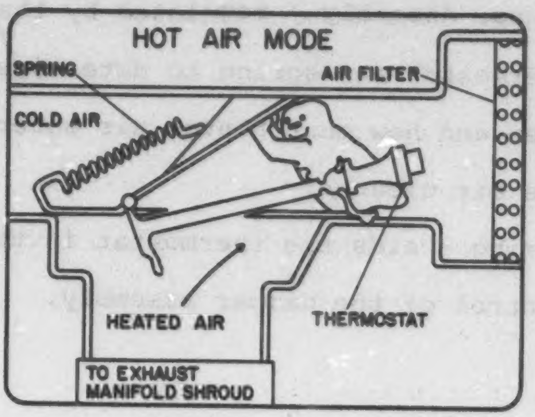

HOT AIR MODE
SPRING
AIR FILTER
COLD AIR
HEATED AIR
THERMOSTAT
TO EXHAUST MANIFOLD SHROUD

Figure 5-6

1. Hot air mode - when under-hood temperatures are below approximately 90°F, the damper assembly blocks cold air. Only heated air is allowed to enter the air cleaner

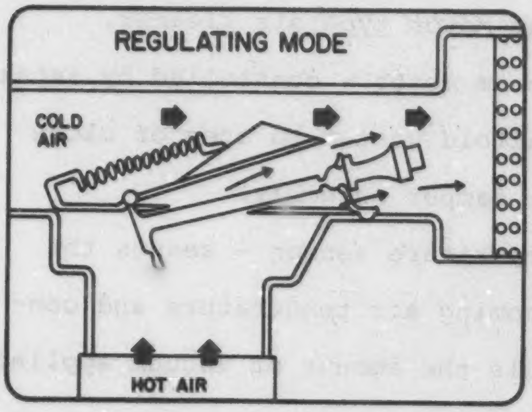

REGULATING MODE
COLD AIR
HOT AIR

Figure 5-7

2. Regulating mode - In this mode the damper assembly allows both heated air and cold air to mix. The air temperature entering the air cleaner is regulated at approximately 100-130°F.

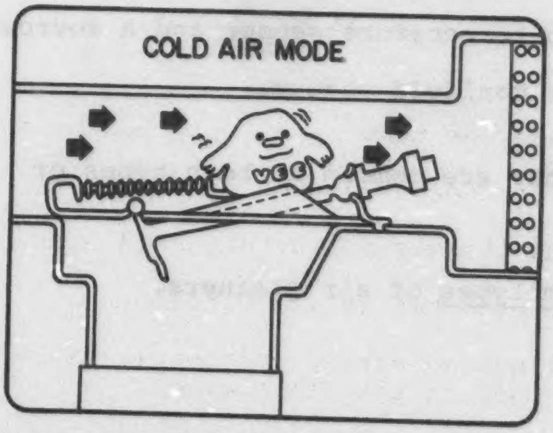

COLD AIR MODE

Figure 5-8

3. Cold air mode - When temperatures inside the air cleaner exceed 120-130°F, the damper assembly blocks off the heated air and allows only cold air to enter the air cleaner.

F. Explain the operation and control of the thermostatic type air cleaner.

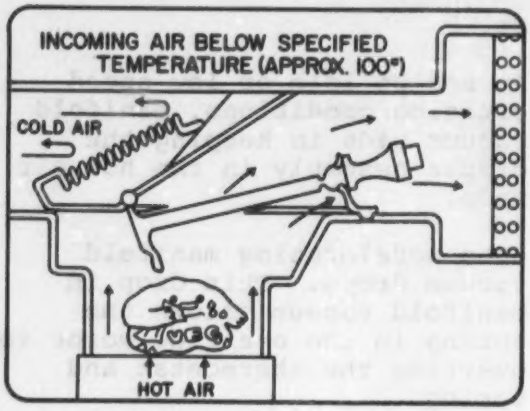

INCOMING AIR BELOW SPECIFIED
TEMPERATURE (APPROX. 100°)
COLD AIR
HOT AIR

Figure 5-9

1. Below approximately 100°F the thermostat is in a retracted position.
   a) This position plus the pull of the spring forces the damper assembly into the position shown.
   b) In this position cold air is prevented from entering the carburetor.
   c) As soon as the engine is started, the exhaust manifold begins to warm up. Air drawn over the exhaust manifold on the way to the carburetor is heated.

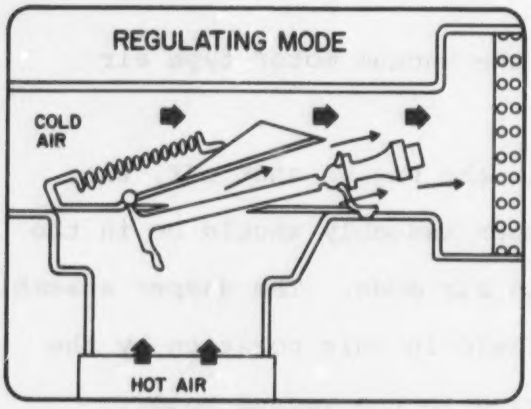

REGULATING MODE
COLD AIR
HOT AIR

Figure 5-10

2. As the heated air temperature rises to approximately 105°F, the thermostat begins to expand.
   a) As the thermostat expands, it pulls against the spring and the damper assembly begins to move down.
   b) This allows some cold air to mix with the heated air.

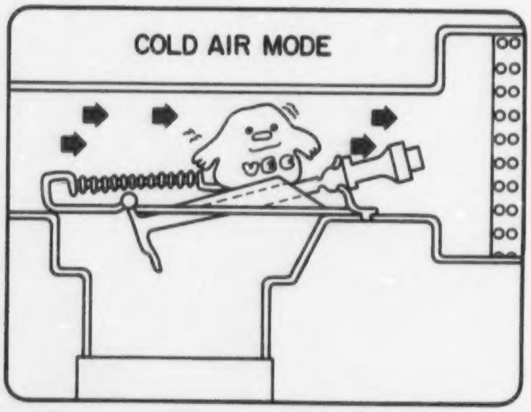

COLD AIR MODE

Figure 5-11

3. When the temperature of the thermostat reaches approximately 130°F, the thermostat has expanded enough to overcome spring tension.
   a) Heated air is completely closed off to the air cleaner.
   b) In this position only cooler under-hood air is entering the carburetor.

4. Some thermostatic air cleaners are equipped with a vacuum override motor.

   a) At engine idle or low speed cruising conditions, manifold vacuum aids in keeping the damper assembly in the hot air mode.

   b) Upon accelerating manifold vacuum drops. This drop in manifold vacuum allows the spring in the override motor to override the thermostat and spring.

   c) The damper assembly moves to the regulated or cold air mode. This provides denser air for more power during acceleration.

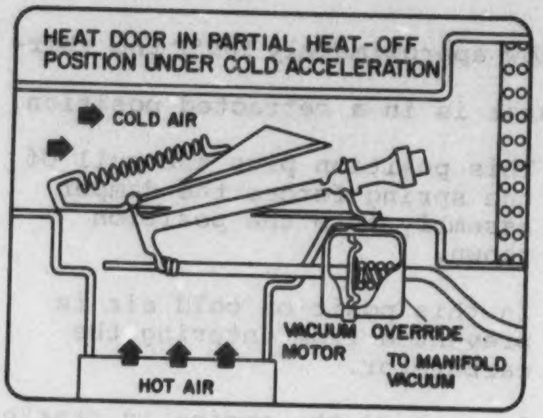

HEAT DOOR IN PARTIAL HEAT-OFF POSITION UNDER COLD ACCELERATION
COLD AIR
VACUUM MOTOR
OVERRIDE
TO MANIFOLD VACUUM
HOT AIR

Figure 5-12

G. Explain the operation and control of the vacuum motor type air cleaner.

1. With the engine shut off, the damper assembly should be in the cold air mode. The damper assembly is held in this position by the spring in the vacuum motor.

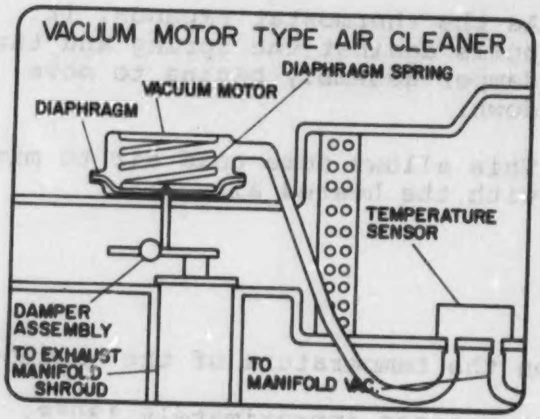

VACUUM MOTOR TYPE AIR CLEANER
DIAPHRAGM SPRING
VACUUM MOTOR
DIAPHRAGM
TEMPERATURE SENSOR
DAMPER ASSEMBLY
TO EXHAUST MANIFOLD SHROUD
TO MANIFOLD VAC.

Figure 5-13

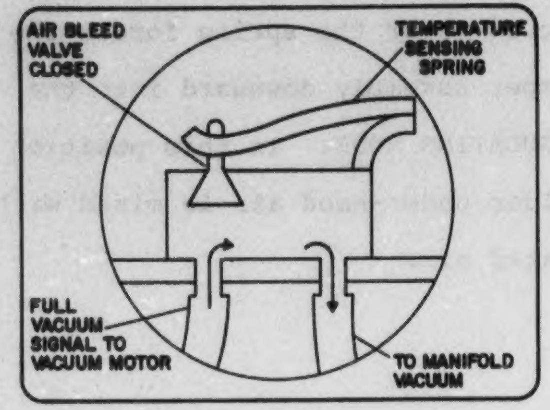

AIR BLEED VALVE CLOSED
TEMPERATURE SENSING SPRING
FULL VACUUM SIGNAL TO VACUUM MOTOR
TO MANIFOLD VACUUM

Figure 5-14

2. When the temperature of temperature sensor is below approximately 85°F, the small air bleed valve is held closed by a temperature-sensitive spring.

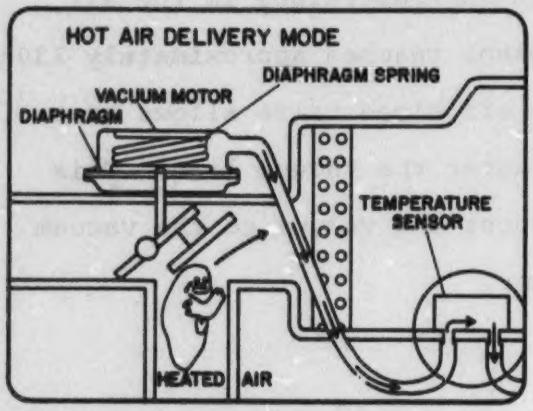

HOT AIR DELIVERY MODE
DIAPHRAGM SPRING
VACUUM MOTOR
DIAPHRAGM
TEMPERATURE SENSOR
HEATED AIR

Figure 5-15

3. When the engine is started, full manifold vacuum reaches the vacuum motor.
   a) Vacuum overcomes the spring tension and the damper assembly moves to the hot air delivery mode.
   b) Air being drawn into the carburetor is preheated by being pulled over the exhaust manifold.

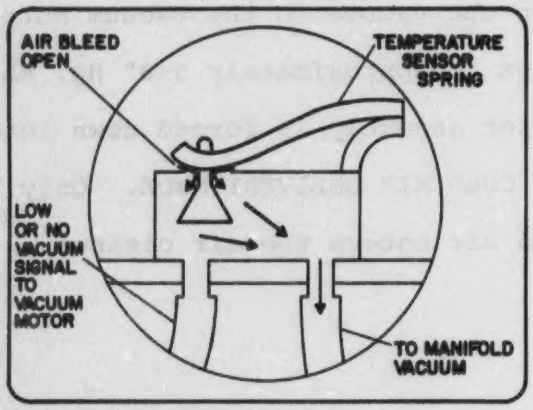

AIR BLEED OPEN
TEMPERATURE SENSOR SPRING
LOW OR NO VACUUM SIGNAL TO VACUUM MOTOR
TO MANIFOLD VACUUM

Figure 5-16

4. As the heated air begins to warm, the temperature-sensitive spring in the temperature sensor, the air bleed valve begins to open. This small air leak destroys some of the vacuum to the vacuum motor. This occurs between 85° to approximately 105°F.

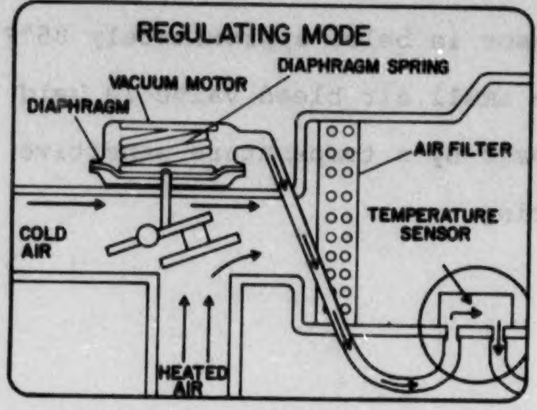

REGULATING MODE
VACUUM MOTOR
DIAPHRAGM SPRING
DIAPHRAGM
AIR FILTER
COLD AIR
TEMPERATURE SENSOR
HEATED AIR

Figure 5-17

5. As the vacuum decreases to the vacuum motor the spring forces the damper assembly downward into the REGULATING MODE. In this position colder under-hood air is mixed with heated air.

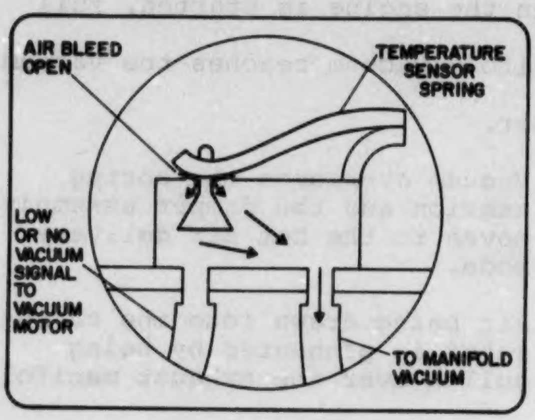

AIR BLEED OPEN
TEMPERATURE SENSOR SPRING
LOW OR NO VACUUM SIGNAL TO VACUUM MOTOR
TO MANIFOLD VACUUM

Figure 5-18

6. When the temperature in the air cleaner reaches approximately 130°F, the air bleed valve allows more air to enter the vacuum line. This reduces the vacuum to the vacuum motor.

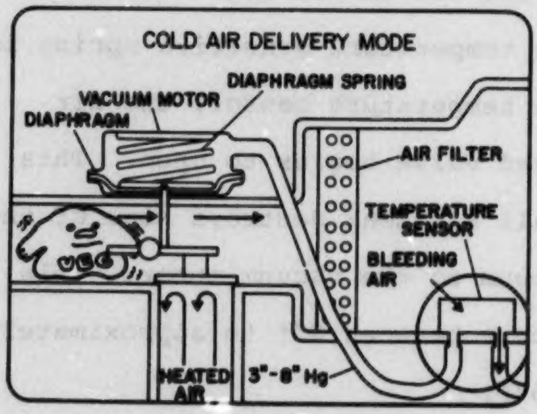

COLD AIR DELIVERY MODE
VACUUM MOTOR
DIAPHRAGM SPRING
DIAPHRAGM
AIR FILTER
TEMPERATURE SENSOR
BLEEDING AIR
HEATED AIR
3"-8" Hg

Figure 5-19

7. When the vacuum to the vacuum motor drops to approximately 3-8" Hg, the damper assembly is forced down into the COLD AIR DELIVERY MODE. Only cold air enters the air cleaner.

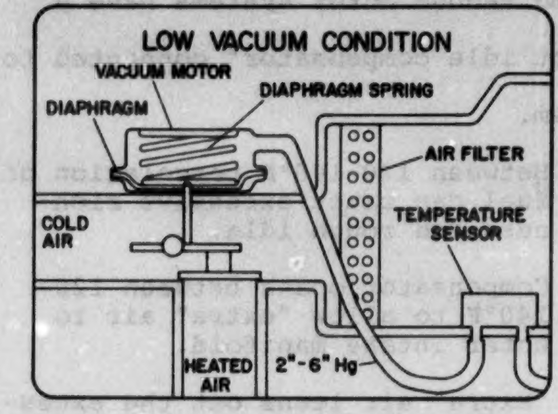

LOW VACUUM CONDITION
VACUUM MOTOR
DIAPHRAGM SPRING
DIAPHRAGM
AIR FILTER
COLD AIR
TEMPERATURE SENSOR
HEATED AIR
2"-6" Hg

Figure 5-20

8. During cold engine acceleration, manifold vacuum drops.
   a) Less vacuum at the vacuum motor allows the spring to force the damper assembly downward.
   b) Cool, dense air is allowed to enter the carburetor for better performance.

H. Explain how heated air systems affect HC/CO emissions and vehicle driveability.

Carburetor idle and off-idle circuits have become progressively leaner since 1968. This, coupled with shorter choke operating times, presents a definite driveability problem.

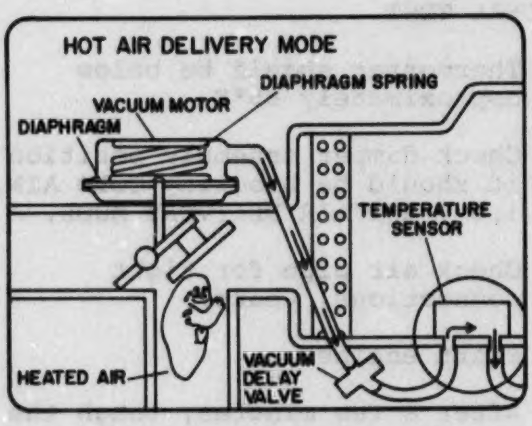

HOT AIR DELIVERY MODE
DIAPHRAGM SPRING
VACUUM MOTOR
DIAPHRAGM
TEMPERATURE SENSOR
HEATED AIR
VACUUM DELAY VALVE

Figure 5-21

1. Heated air to the carburetor allows better fuel vaporization. This in turn:
   a) Gives better fuel distribution.
   b) Increases driveability when cold.
   c) Decreases HC and CO emissions by allowing a leaner air/fuel ratio.
2. Some vacuum motor systems use a small vacuum delay valve in the vacuum motor vacuum line. This prevents:
   a) The damper assembly from rapidly going to the COLD AIR MODE on acceleration.
   b) Lessens hesitation and stumble on acceleration.

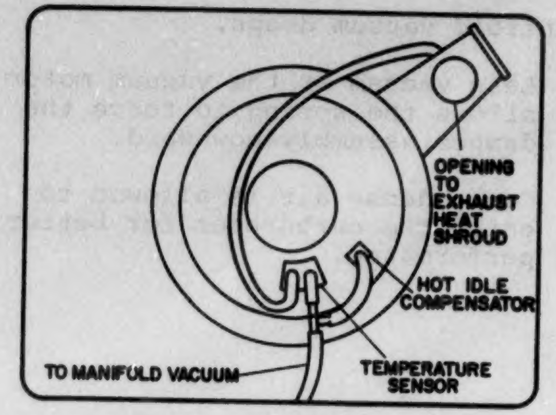


Figure 5-22

3. Some vacuum motor systems have a "hot idle compensator" connected to them.

   a) Between 120-140°F percolation of fuel can cause excessive richness and rough idle.

   b) Compensator opens between 120-140°F to allow "extra" air to enter intake manifold.

   c) "Extra" air leans out the excessive richness.

   d) Improves engine idle quality and reduces HC-CO emissions.

I. Thermostatic Air Cleaner Operational Checks

Explain that the operational checks suggested here are for proper operation of the system. They are visual checks only. Consult a manufacturer's service manual for exact temperature and vacuum specifications. WHEN THESE CHECKS ARE PERFORMED - INSURE AREA IS WELL VENTILATED.

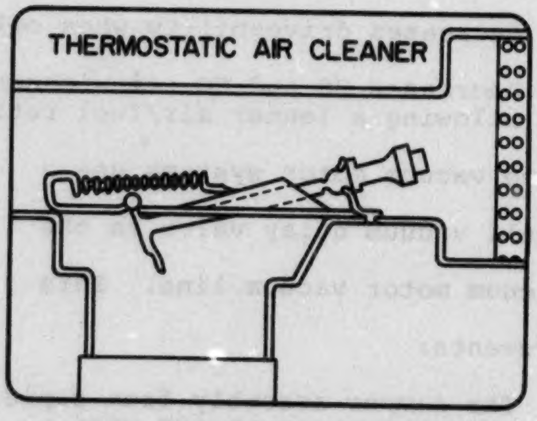


Figure 5-23

1. THERMOSTATIC AIR CLEANER OPERATIONAL TEST.

   a) Thermostat should be below approximately 85°F.

   b) Check damper assembly position - it should be blocking COLD AIR, i.e., HOT AIR DELIVERY MODE.

   c) Check air pipe for tight connections, tears.

   d) Start engine.

   e) After a few minutes, tough the hot air pipe. It should be warming up.

   f) Watch the damper assembly in the air cleaner. It should begin to move out of the hot air delivery mode.

g) If equipped with vacuum override motor, accelerate engine rapidly and return to idle - damper assembly should move down during acceleration, allowing cold air to enter.

h) As the thermostat in the air cleaner becomes warm, the damper assembly should move downward until the heated air inlet is completely blocked, allowing only air to enter.

NOTE: If the thermostatic air cleaner does not operate as described, inspect the spring and damper assembly for binding. Correct as necessary. If no binding is present, the thermostat or temperature sensitive pellet will have to be replaced. CHECK THE MANUFACTURER'S SERVICE MANUAL FOR EXACT PROCEDURES.

2. VACUUM MOTOR OPERATED OPERATIONAL TEST.

a) Temperature sensor should be below approximately 80°F.

b) With the engine shut off, check the damper assembly position. It should be open to cold air.

c) Check air pipe for tight connections at manifold heat shroud and bottom of air cleaner snorkel.

d) Start engine, the damper assembly should move to the hot air mode.

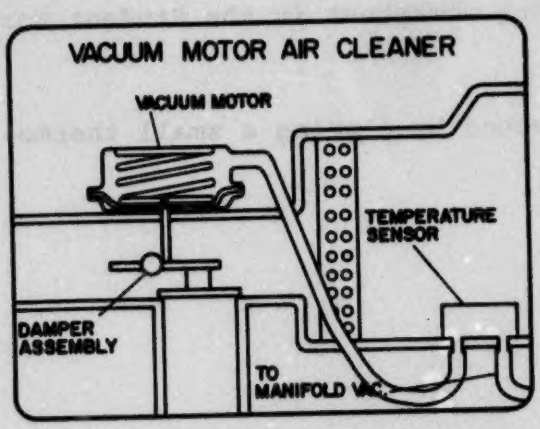


Figure 5-24

NOTE: If the damper assembly does not move to the hot air mode, check the following:

1) Disconnect the vacuum line to the vacuum motor.

2) Connect a vacuum gauge to the vacuum line. It should read full intake manifold vacuum (approximately 16-20" Hg.).

3) If full manifold vacuum is available, check damper assembly for binding. If no binding exists, a new vacuum motor is needed. (Vacuum motor can also be checked using a hand vacuum pump.)

4) If a very low vacuum (3-8" Hg.) is shown, the temperature sensor must be replaced.

e) As the engine and air cleaner assembly warm up, the damper assembly should go into the regulating mode and then the cold air mode.

NOTE: If the damper assembly does not follow this sequence, the temperature sensor must be replaced. CHECK THE MANUFACTURER'S SERVICE MANUAL FOR EXACT PROCEDURES.

Have your students fill out the following worksheet in the Student Workbook as they perform the tests.

NOTE: Exact temperatures can be checked by placing a small thermometer inside the air cleaner.

THERMOSTATIC AIR CLEANER WORKSHEET

Engine Speed	Test Conditions	Cold Air Mode	Regulating Mode	Hot Air Delivery Mode
THERMOSTATIC TYPE				
Off	Temperature Below 80°F			
Idling	Temperature Between 100-130°F			
If equipped with vacuum override motor				
Snap Acceleration	Temperature Between 100-130°F			
Idling	Temperature Above 130°F			
VACUUM MOTOR TYPE				
Off	Check Position			
Idling	Temperature Below 80°F			
Idling	Temperature Between 100-120°F			
Idling	Temperature Above 130°F			

UNIT 6

AIR INJECTION SYSTEMS

- BACKGROUND INFORMATION -

Approximately 60% of the hydrocarbons and carbon monoxide that make up automobile emissions are discharged out of the tailpipe. These emissions result from incomplete combustion or burning in the engine. One very important element necessary for combustion to occur is oxygen. Since the air we breathe is made up of approximately 20% oxygen, air can be injected very close to the outlet side of the exhaust valve. When air is injected in this location, it allows the burning of the air/fuel mixture to continue in the exhaust system of the car thereby reducing the amount of HC and CO exhausted to the atmosphere.

The air injection system has been used by the car makers off and on since 1967. It is a very effective method for reducing the HC and CO emissions from the internal combustion engine.

The air injection system has many different names. Each manufacturer has their own special name for it. All of these systems are very similar and perform the same job. Don't let the names confuse you.

A. Explain the main components of the Air Injection System.

1. Air Pump - A belt driven pump that supplies air to the air injection system.
2. Diverter Valve - Prevents air from entering the exhaust system during deceleration. This prevents backfiring. It also acts as a pressure relief valve.

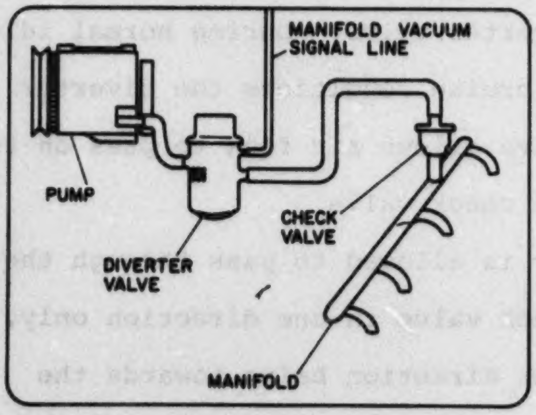


Figure 6-1

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3. Check Valve - Allows air flow into the exhaust manifold and prevents the exhaust gases from entering the air injection systems.
4. Air Distribution Manifold - Directs the air to the vicinity of each cylinder's exhaust valve.
5. Manifold Vacuum Signal Line - Provides manifold vacuum signal to diverter valve.

B. Explain the air flow through the system during normal engine operation.

1. Air is drawn into the pump through a centrifugal filter. The centrifugal filter is a small, plastic, round filter behind the belt pulley. This filter has vaned openings to prevent the entrance of foreign particles into the pump.
2. Air from the pump is forced into a diverter valve. During normal idle or cruise conditions the diverter valve allows air flow to pass on to the check valve.
3. Air is allowed to pass through the check valve in one direction only, that direction being towards the air distribution manifold.

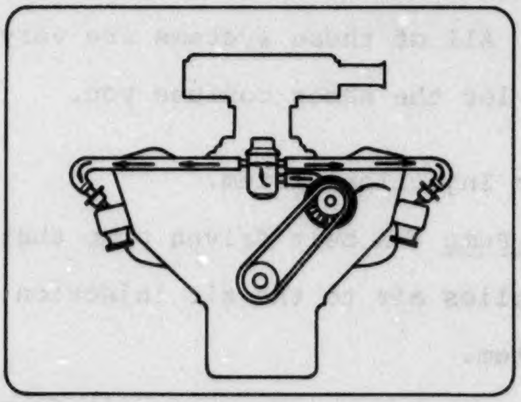


Figure 6-2

4. Air enters the distribution manifold and is evenly distributed to the exhaust part of each cylinder.

5. As the air comes in contact with the hot exhaust gases, the exhaust gases continue to burn. This reduces the amount of HC and CO that is exhausted out of the tailpipe.

C. Explain the operation of the diverter valve during normal operation.

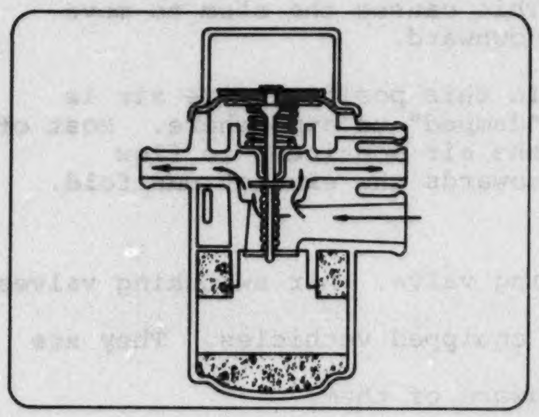


Figure 6-3

1. During idle and cruise conditions, air flow through the diverter valve is as shown. Air enters the diverter valve, flows around the stem and open upper valve and is directed out to the air distribution manifold.

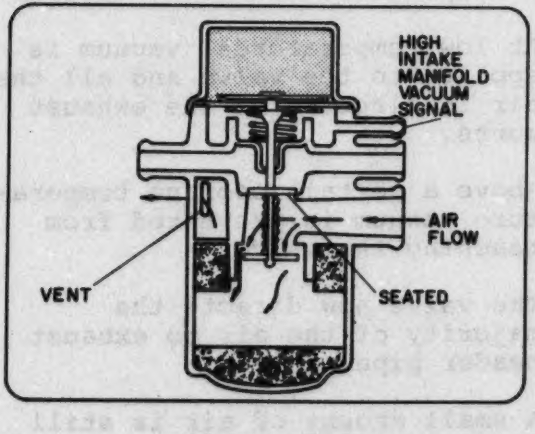


Figure 6-4

2. During deceleration:

   a) A manifold vacuum sensing line senses the sharp increase in intake manifold vacuum when the throttle closes.

   b) The increase in intake manifold vacuum pulls down a diaphragm.

   c) When this diaphragm is pulled down, the air is prevented from passing to the check valves and air distribution manifold.

   d) The air is directed downward, through silencing material and out to the atmosphere.

e) This "dump" condition lasts 2-4 seconds. A small orifice allows vacuums to equalize on both sides of the diaphragm. When vacuums equalize, normal air flow is restored.

D. Explain the operation of the diverter valve when excessive pressure builds up in the diverter valve.

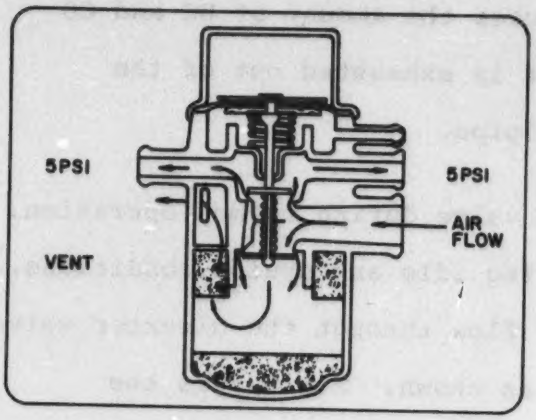


Figure 6-5

1. The diverter valve acts as a relief valve when air pressure becomes excessive.

   a) Pressure works against the lower valve.

   b) This causes the stem to move downward.

   c) In this position some air is "dumped" to atmosphere. Most of the air continues to flow towards the exhaust manifold.

E. Explain the purpose of the air switching valve. Air switching valves are found on some catalytic converter equipped vechicles. They are included here so students can become aware of them.

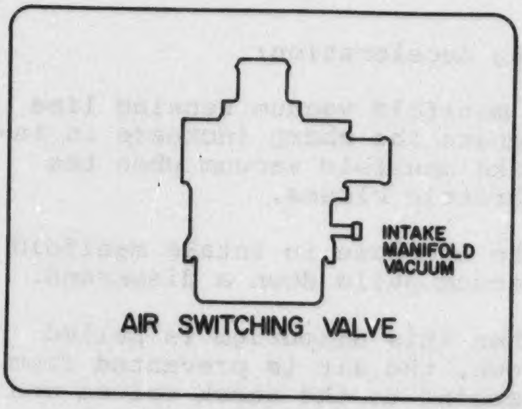


Figure 6-6

a) The source of vacuum to the air switching valve is controlled by a temperature sensitive switch.

b) At low temperatures, vacuum is applied to the valve and all the air is directed to the exhaust ports.

c) Above a certain coolant temperature vacuum is prevented from reaching the valve.

d) The valve now directs the majority of the air to exhaust header pipe.

e) A small amount of air is still directed to the exhaust ports.

F. Explain the operation of the air injection system check valve.

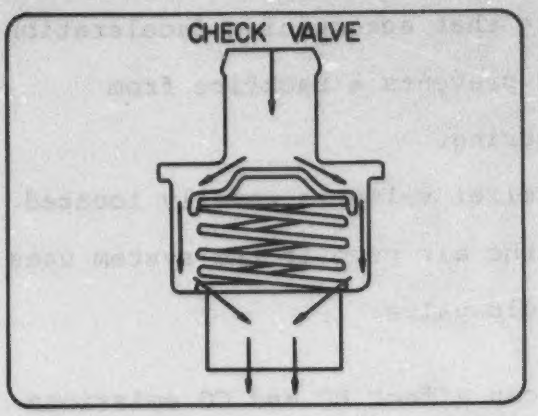

CHECK VALVE

Figure 6-7

1. The check valve has a spring loaded steel diaphragm.
2. Air can flow from the pump to the exhaust manifold.

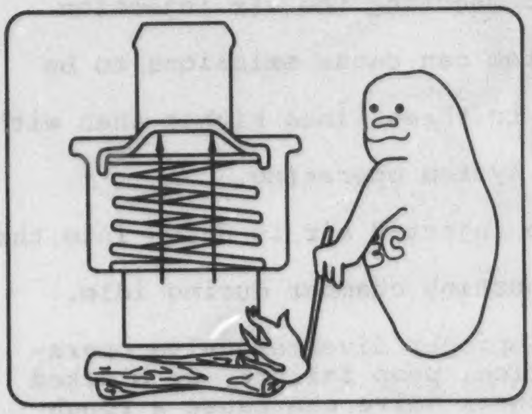


Figure 6-8

3. In case of pump belt breakage, hose rupture, or excessive exhaust back pressure, the steel diaphragm prevents exhaust gas from reaching air system components.

G. Explain the operation of the "Gulp" valve.

Gulp valves are used on some vehicles instead of a diverter valve.

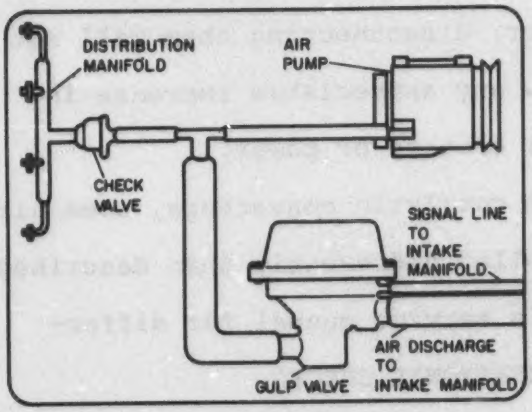

DISTRIBUTION MANIFOLD
AIR PUMP
CHECK VALVE
SIGNAL LINE TO INTAKE MANIFOLD
AIR DISCHARGE TO INTAKE MANIFOLD
GULP VALVE

Figure 6-9

1. The gulp valve is used to prevent backfire during deceleration.
2. The gulp valve is operated by the sharp increase in manifold vacuum that accompanies deceleration.
3. This increase in vacuum causes the gulp valve to vent a portion of pump air into the intake manifold.

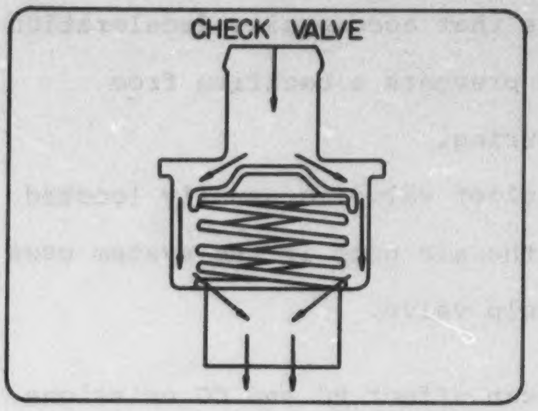
4. This air "leans out" the rich mixture that accompanies deceleration and prevents a backfire from occuring.
5. A relief valve is usually located on the air pump if the system uses a gulp valve.

H. Explain how the air injection system can affect HC and CO emissions and driveability.

1. Disconnecting the air injection system can cause emissions to be two to three times higher than with the system operating.
2. Some injected air is drawn into the combustion chamber during idle.
    a) Improper diverter valve operation, pump failure, or blocked check valve can cause a rough idle condition if air flow is blocked.
3. Improper diverter valve operation can cause backfires to occur.
4. Air pumps require very little power; disconnecting them will not show any appreciable increase in fuel economy or power.

NOTE: On 1975 and newer vehicles with catalytic converters, some air injection systems may be controlled differently than described above. Check the manufacturer's service manual for differences BEFORE conducting any OPERATIONAL CHECKS.

F. Explain the operation of the air injection system check valve.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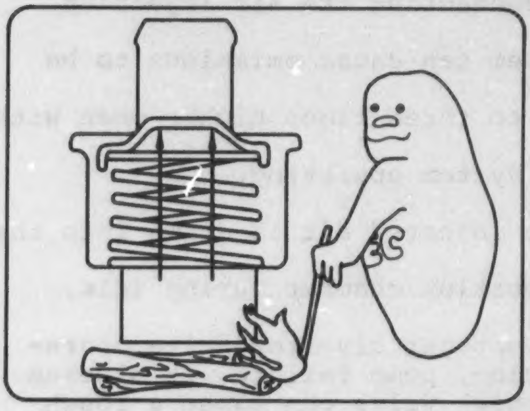

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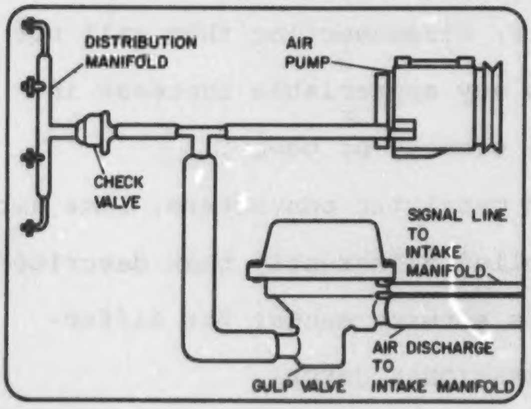
DISTRIBUTION MANIFOLD
AIR PUMP
CHECK VALVE
SIGNAL LINE TO INTAKE MANIFOLD
AIR DISCHARGE TO INTAKE MANIFOLD
GULP VALVE

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NOTE: On 1975 and newer vehicles with catalytic converters, some air injection systems may be controlled differently than described above. Check the manufacturer's service manual for differences BEFORE conducting any OPERATIONAL CHECKS.

I. Air Injection System Operational Checks.

The following suggested operational checks will show whether or not the system is operating. It is strongly suggested that the proper manufacturer's service manual is referred to for additional checks and specific procedures.

WHEN PERFORMING ANY CHECKS THAT REQUIRE THE ENGINE TO BE RUNNING, INSURE WORK AREA IS WELL VENTILATED.

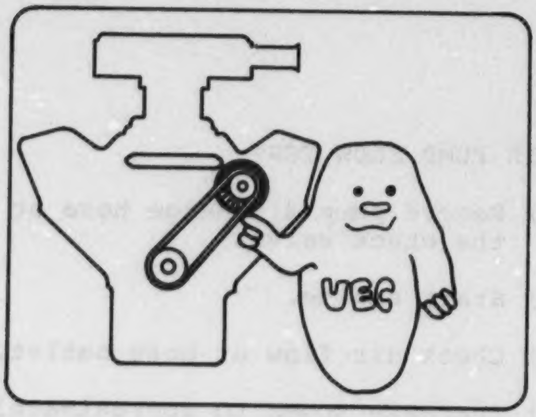


Figure 6-10

1. AIR PUMP DRIVE BELT

   a) Check belt for wear and proper tension (manufacturer's service manual). Loose belts slip, glaze, squeal and prevent proper pump operation. Belts that are too tight can cause early bushing and/or bearing failures.

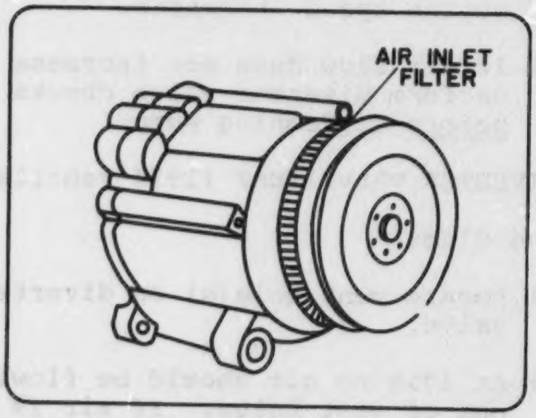


Figure 6-11

2. CENTRIFUGAL FILTER

   A) Visually inspect for excessive wear or breakage.

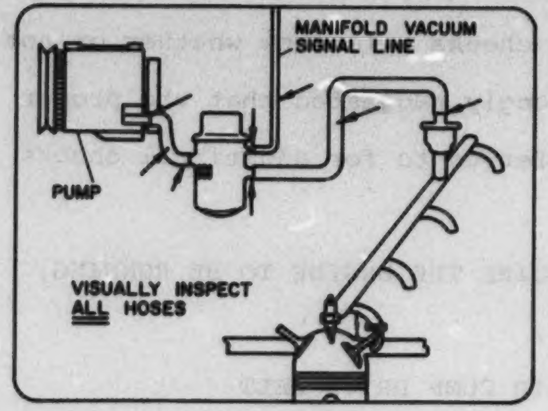


Figure 6-12

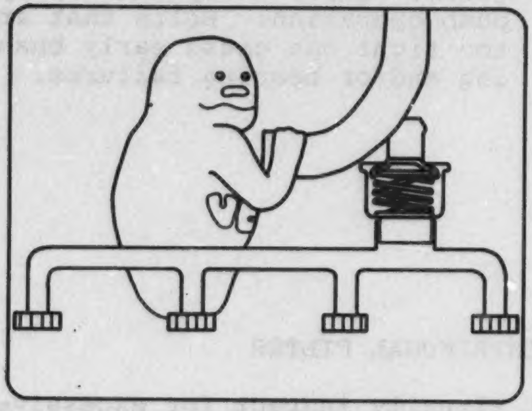


Figure 6-13

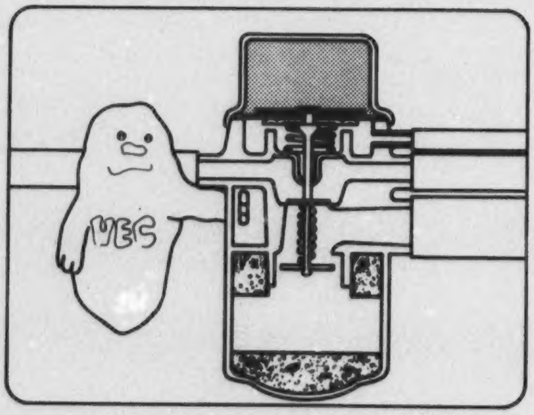


Figure 6-14

3. VISUAL INSPECTION OF ALL HOSES - AIR AND VACUUM

a) Visually inspect all hoses for
   1) Loose connections
   2) Worn spots
   3) Excessive brittleness
   4) Sharp bends that pinch off air flow or vacuum

Correct as necessary.

4. AIR PUMP FLOW TEST

a) Remove pump discharge hose at the check valve.

b) Start engine.

c) Check air flow at hose outlet.

d) Increase speed to approximately 1500 rpm.

e) Air flow should increase as engine speed increases.

f) If air flow does not increase perform diverter valve checks before condemning pump.

5. DIVERTER VALVE TEST (1974 vehciles and older)

a) Locate vent hole(s) on diverter valve.

b) At idle no air should be flowing out of vent holes. If air is being dumped at idle, a new diverter valve is needed. (This could cause the iar pump flow not to increase in air pump test.)

c) Increase engine speed to approximately 2000 rpm.

d) Let throttle close rapidly. Air should be dumped for 1-3 seconds during this time.

e) If vacuum is present, diverter valve should be replaced. Not dumping can cause backfiring. If diverter does not dump on deceleration, remove vacuum sensing hose and check for vacuum. A strong vacuum should be felt anytime the engine is running.

6. CHECK VALVE TEST

a) Remove hose from check valve(s).

b) Start engine.

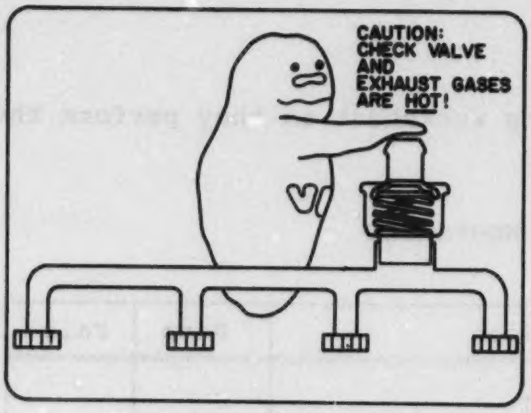


Figure 6-15

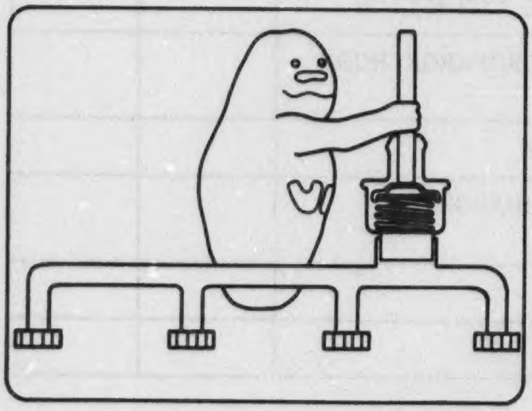


Figure 6-16

c) Hold your hand over the check valve opening. If no exhaust is felt, check valve is O.K. Use a pencil or other narrow object to push down on check valve diaphragm. Diaphragm should move freely; if not, replace check valve. If exhaust pulsations are felt, check valve is acceptable. If a solid flow of exhaust gas if felt, check valve should be replaced.

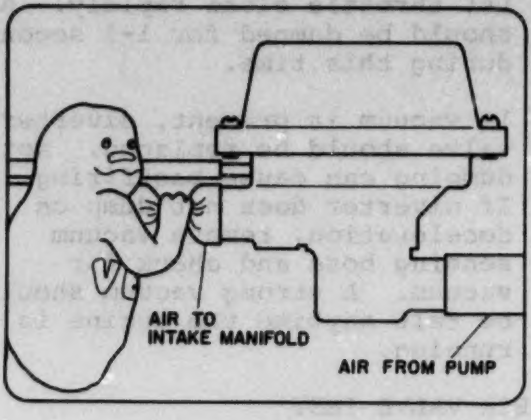


Figure 6-17

7. GULP VALVE TEST

a) Pinch hose closed between gulp valve and intake manifold. Engine speed should not change. If it does, this means the gulp valve is leaking and should be replaced.

b) Remove the manifold vacuum sensing line for approximately five seconds. Then reconnect line. If engine idle changes when line is reconnected gulp valve is operating properly.

Have your students fill out the following worksheet as they perform the tests.

AIR INJECTION SYSTEM WORKSHEET

Engine Speed	Test Condition	Pass	Fail
0	AIR PUMP DRIVE BELT		
0	CENTRIFUGAL FILTER		
0	AIR AND VACUUM HOSE CONDITION		
Idle and 1500 rpm	PUMP AIR FLOW AT DISCHARGE HOSE END		
Idle	DIVERTER VALVE TEST		
2000 rpm	DIVERTER VALVE DISCHARGE ON DECELERATION		
Idle	GULP VALVE TEST		
Idle	GULP VALVE TEST		

UNIT 7

FUEL EVAPORATION CONTROL

- BACKGROUND INFORMATION -

Up to this point the control of hydrocarbon emissions by the PCV system, Thermostatic Air Cleaner and Air Injection System have been discussed. All of these relate directly to the combustion process within the engine. However, when gasoline evaporates, unburned hydrocarbons enter the atmosphere. It has been estimated that approximately 20% of the total hydrocarbon emissions result from the evaporation of gasoline in the carburetor and fuel tank. Consequently, all cars sold in the United States since 1971 were required to have some type of fuel evaporative control system for these evaporative HC emissions.

Earlier, pre-emissions fuel tanks drew air in through the fuel filler cap as gasoline was used. When the fuel expanded in the tank, gasoline vapors were simply pushed back out of the fuel filler cap to atmosphere. Gasoline vapors from earlier carburetor fuel bowls were allowed to escape to atmosphere as well. The Fuel Evaporation Control system (FEC) now controls this source of hydrocarbon emissions.

A. Explain the main components of the Fuel Evaporation Control system. Figure 6-7 shows a typical fuel evaporation control system. Exact components may vary in physical description but the concept is the same for all systems.

1. Fuel Tank - Fuel tanks have been redesigned to provide approximately 10% air space for the expansion of fuel as temperatures increase.

2. Fuel Tank Filler Caps - Prevent the escape of gasoline vapors to atmosphere under normal operating conditions.

3. Liquid-Vapor Separator - Separates liquid fuel from the vapors. The liquid fuel is returned to the fuel tank.

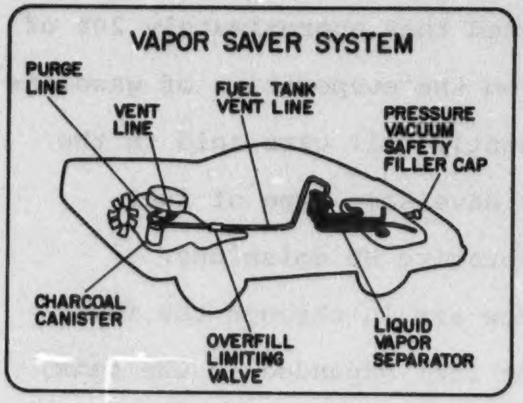

VAPOR SAVER SYSTEM
PURGE LINE
VENT LINE
FUEL TANK VENT LINE
PRESSURE VACUUM SAFETY FILLER CAP
CHARCOAL CANISTER
OVERFILL LIMITING VALVE
LIQUID VAPOR SEPARATOR

Figure 7-1

4. Fuel Tank Vent Line - Routes the vapors from the liquid vapor separator forward to the overfill limiting valve.

5. Overfill Limiting Valve - Prevents any liquid fuel that enters the vent line from reaching the charcoal canister. (This part is not found in all systems.)

6. Charcoal Canister - Stores the fuel vapors in activated charcoal.

7. Purge Line - Provides a means for drawing fresh air through the canister to remove or purge fuel vapors out of the activated charcoal and delivering these vapors to the engine to be burned.

Note: In 1976 a design requirement for all cars was to pass a 360° roll over test without losing any liquid fuel. Many of the devices that prevent loss of fuel are a part of newer fuel evaporation control systems. Consult the manufacturer's service manual for specific information on these parts. This is necessary for proper repair and to maintain fuel system integrity in the event of vehicle rollover.

B. Explain the operation of the Fuel Evaporation Control system.

1. Fuel tank filler necks have been changed to prevent the tank from being completely filled. The lower position of the filler necks allow approximately 10% air expansion space above the fuel level.

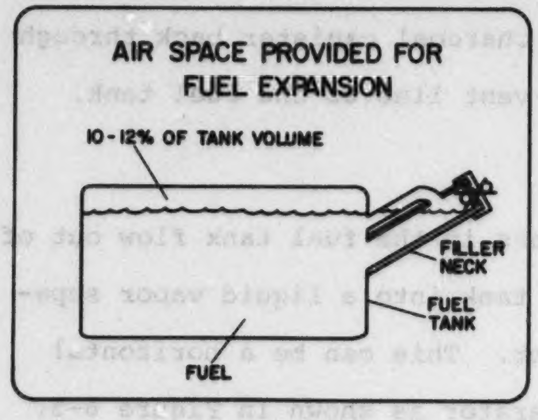

AIR SPACE PROVIDED FOR FUEL EXPANSION
10-12% OF TANK VOLUME
FILLER NECK
FUEL TANK
FUEL

Figure 7-2

2. When the filler cap is reinstalled, fuel vapors are trapped in the tank. Fuel tank caps incorporate a built-in pressure relief valve and a vacuum relief valve. The pressure relief valve will vent excessive pressure to atmosphere - only if there is a blockage in the vent line to the canister.

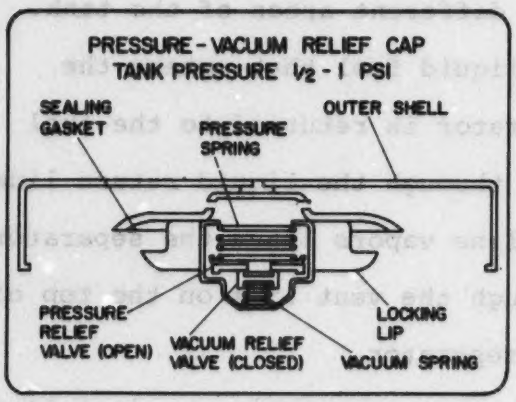

PRESSURE-VACUUM RELIEF CAP
TANK PRESSURE 1/2 - 1 PSI
SEALING GASKET
PRESSURE SPRING
OUTER SHELL
PRESSURE RELIEF VALVE (OPEN)
VACUUM RELIEF VALVE (CLOSED)
LOCKING LIP
VACUUM SPRING

Figure 7-3

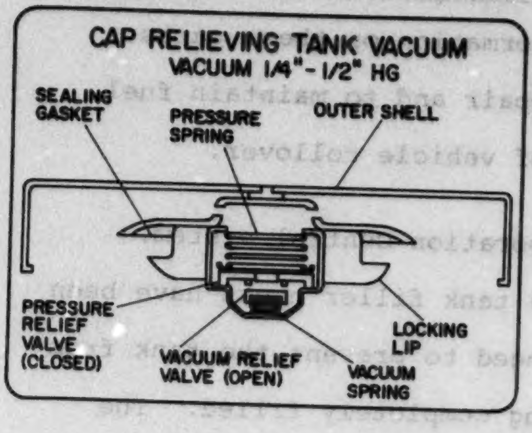

CAP RELIEVING TANK VACUUM
VACUUM 1/4" - 1/2" HG
SEALING GASKET
PRESSURE SPRING
OUTER SHELL
PRESSURE RELIEF VALVE (CLOSED)
LOCKING LIP
VACUUM RELIEF VALVE (OPEN)
VACUUM SPRING

Figure 7-4

3. The cap will also allow air to enter the fuel tank if an excessive vacuum (approximately 1/2"-1" Hg) develops in the tank.

   NOTE: The normal vent path for air to enter the fuel tank is from the charcoal canister back through the vent line to the fuel tank.

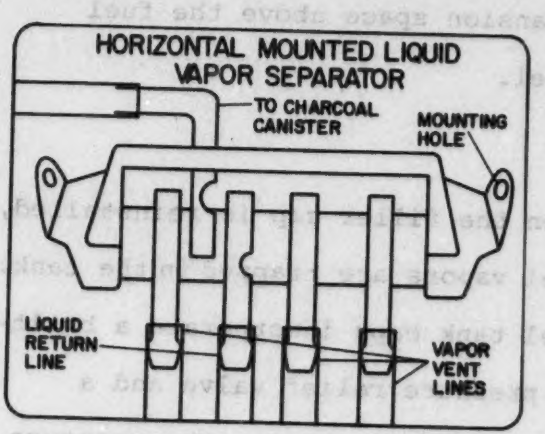

HORIZONTAL MOUNTED LIQUID VAPOR SEPARATOR
TO CHARCOAL CANISTER
MOUNTING HOLE
LIQUID RETURN LINE
VAPOR VENT LINES

Figure 7-5

4. Vapors in the fuel tank flow out of the tank into a liquid vapor separator. This can be a horizontal separator as shown in Figure 6-5. Vent lines enter this separator from different areas of the tank. Any liquid fuel that enters the separator is returned to the fuel tank through the liquid return line. Gasoline vapors leave the separator through the vent line on the top of the separator.

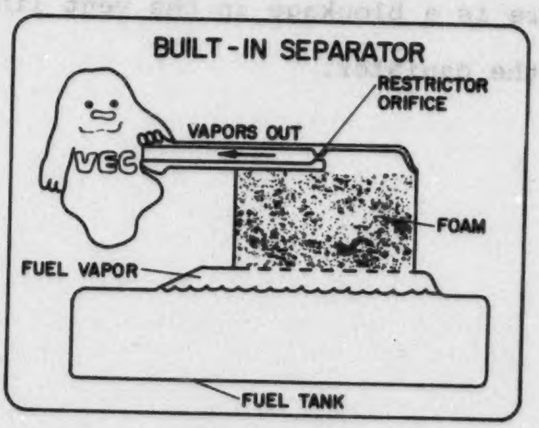

BUILT-IN SEPARATOR
RESTRICTOR ORIFICE
VAPORS OUT
VEC
FOAM
FUEL VAPOR
FUEL TANK

Figure 7-6

5. Some vapor separators are installed in the top of the fuel tank as shown in Figure 6-6. An open cell foam allows vapors to pass through but restricts the flow of liquid fuel.

   NOTE: There are many types of Liquid Vapor Separators. Consult the manufacturer's service manual for the vehicle you are working on.

6. Fuel vapors pass forward to the charcoal canister. Activated charcoal in the canister adsorbs the vapors. These stored vapors are prevented from escaping to atmosphere. When the engine is started these vapors are drawn into the engine and burned.

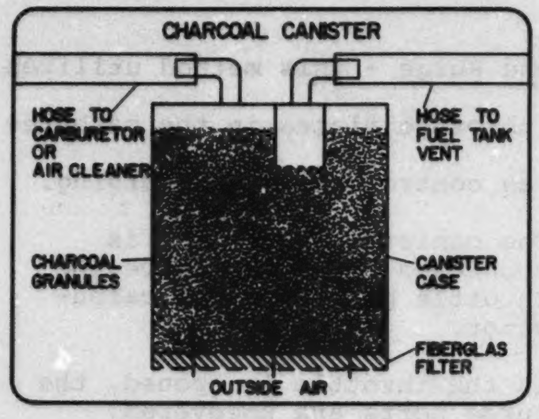

CHARCOAL CANISTER
HOSE TO CARBURETOR OR AIR CLEANER
HOSE TO FUEL TANK VENT
CHARCOAL GRANULES
CANISTER CASE
FIBERGLAS FILTER
OUTSIDE AIR

Figure 7-7

C. Explain the different methods used to purge fuel vapors from the charcoal canister.

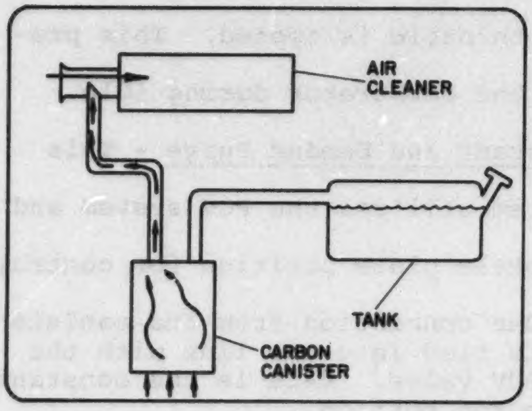

AIR CLEANER
TANK
CARBON CANISTER

Figure 7-8

1. Variable Purge - This method utilizes the air flow into the air cleaner to purge the charcoal canister.
    a) A tube in the air cleaner snorkel senses differences in air flow.
    b) As engine speed is increased, more air flows by the tube.
    c) The low pressure created in the tube draws air into the bottom of the charcoal canister.
    d) The air passes over the charcoal and lifts off the gasoline vapors.
    e) The air and vapors are drawn into the air cleaner and burned in the engine.

The variable purge depends on engine speed. The higher the engine speed, the greater the air flow and the greater the purge rate on the canister.

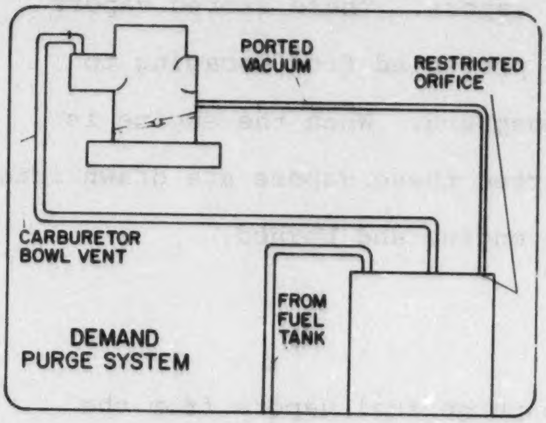

PORTED VACUUM
RESTRICTED ORIFICE
CARBURETOR BOWL VENT
FROM FUEL TANK
DEMAND PURGE SYSTEM

Figure 7-9

2. Demand Purge - This method utilizes the throttle plates in the carburetor as control valve for purging.
   a) The canister purge line is connected to a port above the throttle plates in the carburetor.
   b) As the throttle is opened, the purge ports are uncovered.
   c) A low pressure is created in the purge line to the canister.
   d) The low pressure created causes air to be drawn through the charcoal canister towards the carburetor.
   e) The fuel vapors drawn from the canister with the air are pulled into the engine and burned.

The demand purge only purges when the throttle is opened. This prevents extra fuel vapors from entering the carburetor during idle.

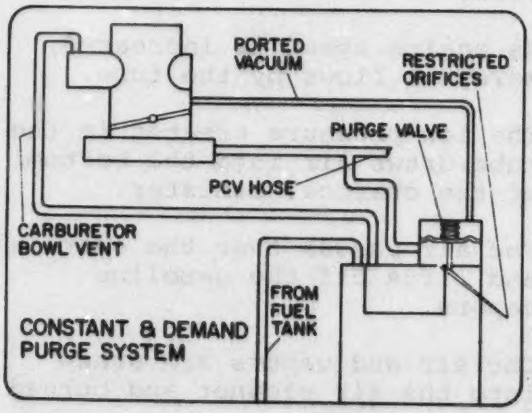

PORTED VACUUM
RESTRICTED ORIFICES
PURGE VALVE
PCV HOSE
CARBURETOR BOWL VENT
FROM FUEL TANK
CONSTANT & DEMAND PURGE SYSTEM

Figure 7-10

3. Constant and Demand Purge - This system utilizes the PCV system and throttle plate position for control.
   a) One connection from the canister is tied into the line with the PCV valve. This is the constant purge portion.
   b) A small restriction in the canister limits the purge rate during idle. The small amount that is purged is drawn in with blowby gases and burned in the engine.
   c) When the throttle is opened, A vacuum signal opens the purge valve on the canister. This

allows a higher canister purge rate at increased engine speed.

D. Explain the operation of carburetor fuel bowl vents.

The carburetor was another source of hydrocarbon emissions. This is especially true when the engine is idling or shut off. Carburetors are now vented internally or to the canister to limit evaporative emissions.

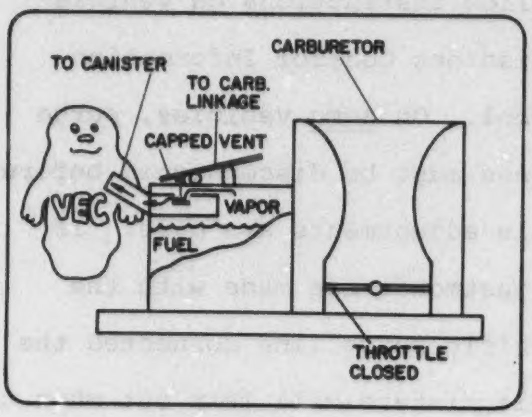

TO CANISTER
CARBURETOR
TO CARB. LINKAGE
CAPPED VENT
VEC
VAPOR
FUEL
THROTTLE CLOSED

Figure 7-11

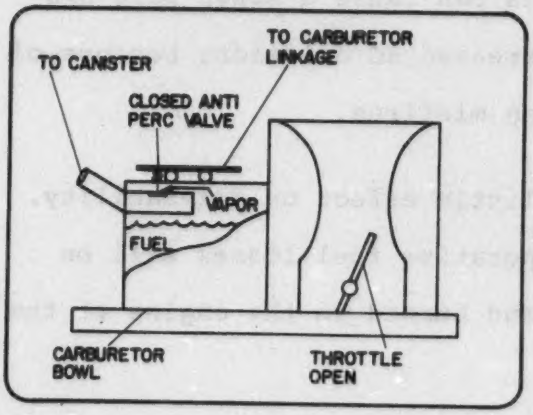

TO CARBURETOR LINKAGE
TO CANISTER
CLOSED ANTI PERC VALVE
VAPOR
FUEL
CARBURETOR BOWL
THROTTLE OPEN

Figure 7-12

1. When the throttle is in the idle position, a small valve is mechanically opened. This small valve allows fuel vapors to pass from the carburetor float bowl to the charcoal canister. Venting is allowed anytime the throttle is at idle position, regardless if the engine's running or stopped.
2. As the throttle is opened, the fuel bowl vent valve closes. Venting does not occur when the throttle is opened.

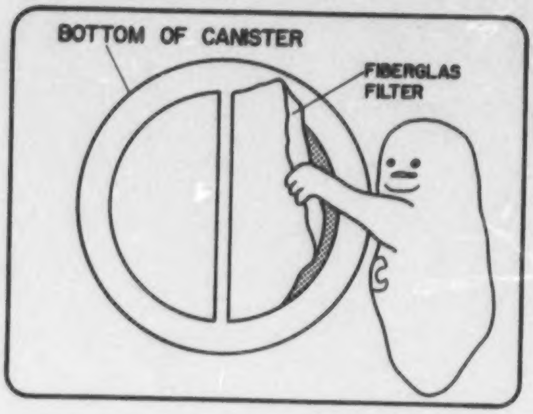
E. Explain how the FEC system can affect HC/CO emissions and driveability.

1. Loose hose connections can allow fuel vapors to enger the atmosphere (HC emissions).
2. Torn seals on fuel tank filler caps can allow fuel vapors to enter the atmosphere (HC emissions).
3. During carburetor idle adjustment, follow instructions on Vehicle Emissions Control Information Label. On some vehicles, purge lines must be disconnected before idle adjustments are made. If adjustments are made with the vehicle purge line connected the idle mixture will lean out when the canister is thoroughly purged. This can cause a rough idle and increased HC emissions because of lean misfires.

Except as noted, the FEC system has little effect on driveability. If a tight system is maintained, evaporative fuel losses will be minimal. The vapors will be stored and burned in the engine at the proper time.

F. Fuel Evaporation Control Maintenance Checks.

a) Check the condition of the fiberglass filter on the bottom



of the charcoal canister. Replace as directed by the OWNER'S MAINTENANCE SCHEDULE BOOK.

b) Check all hose connections for tightness.

c) Check seal on fuel tank filler cap. If torn or cracked, replace cap. Insure proper replacement cap is installed.

Figure 7-13

NOTE: If any hoses in the FEC system must be replaced, use only the proper fuel resistant hose.

Have the students fill out the following worksheet in the student's workbook as they perform the tests.

Engine Speed	Test Condition	Pass	Fail
0	VISUAL INSPECTION Fuel tank filler cap		
0	Fuel tank and hose connection condition		
0	Liquid vapor separator and/or check valve condition		
0	Type of purge system		
0	Canister line condition		
0	Filter condition		

UNIT 8

EXHAUST GAS RECIRCULATION

- BACKGROUND INFORMATION -

One pollutant from motor vehicles not yet discussed is NO_x. NO_x or oxides of nitrogen result from the high temperatures of the combustion process. When air and fuel are burned in the internal combustion engine, temperatures up to 4500°F can be reached. NO_x is formed very rapidly above approximately 2500°F. In 1973 federal standards were established to limit the amount of NO_x resulting from the combustion process in the internal combustion engine. The auto manufacturers chose the exhaust gas recirculation system (EGR) as the primary means of controlling NO_x emissions. The EGR system allows a small amount of burned exhaust gas to be mixed, in the intake manifold, with the incoming air/fuel mixture. The inert exhaust gas dilutes the air/fuel mixture. Dilution results in lower combustion chamber temperatures and controls NO_x emissions.

A. Explain the purpose of the EGR valve.

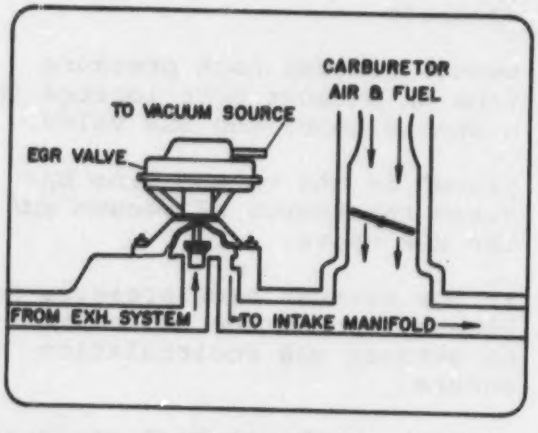


Figure 8-1

1. The EGR valve controls the amount of exhaust gas recirculated back to intake manifold.
2. Directly below the EGR valve is an opening to the exhaust system. As the EGR valve opens, exhaust gas passes into the intake manifold to dilute the air/fuel mixture.
3. The EGR valve is opened by a vacuum signal. This vacuum signal must be carefully controlled to insure exhaust gas recirculation occurs at

Preceding page blank

the proper time in engine operation.

B. Identify and explain the components that can be used to control the operation of the EGR valve.

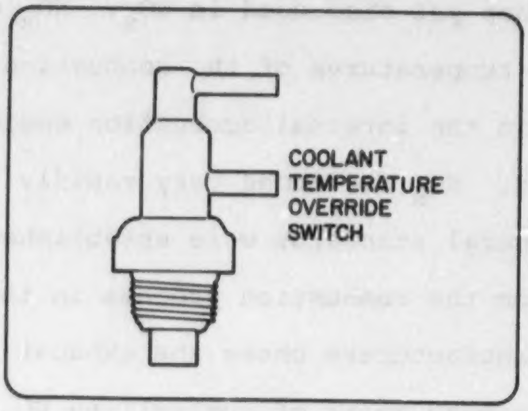


Figure 8-2

1. Coolant temperature override switch (CTO)
   a) normally located in intake manifold coolant passages.
   b) temperature sensitive switch
   c) normally senses engine coolant temperature
   d) placed in the vacuum line between the source of vacuum and the EGR valve.
   e) at low coolant temperature - no vacuum is allowed to EGR valve
   f) at preset temperature switch opens and allows vacuum to reach the EGR valve.

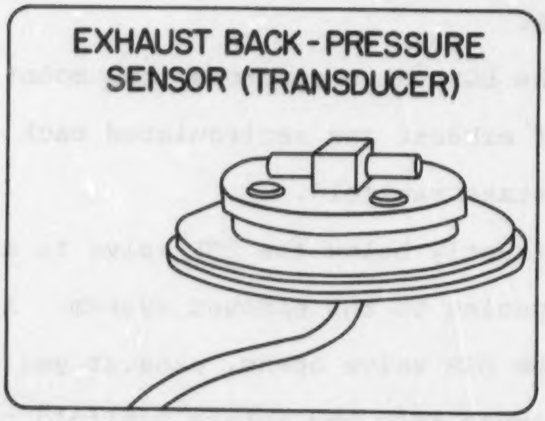


Figure 8-3

2. Exhaust Back Pressure Sensor (Transducer)
   a) senses exhaust system back pressure
   b) senses exhaust back pressure from an exhaust port located in a spacer under the EGR valve.
   c) placed in the vacuum line between the source of vacuum and the EGR valve.
   d) at low exhaust back pressure no vacuum reaches the EGR valve - no exhaust gas recirculation occurs.
   e) at higher exhaust back pressure vacuum is allowed to reach the EGR valve and exhaust gas recirculation occurs.

3. Vacuum Amplifier

a) senses carburetor venturi vacuum

b) uses the small carburetor venturi vacuum signal to control intake manifold vacuum

c) regulated intake manifold vacuum is then used to control the EGR valve

d) venturi vacuum signal is proportional to air flow through the carburetor

e) as engine speed and air flow increase exhaust gas recirculation occurs

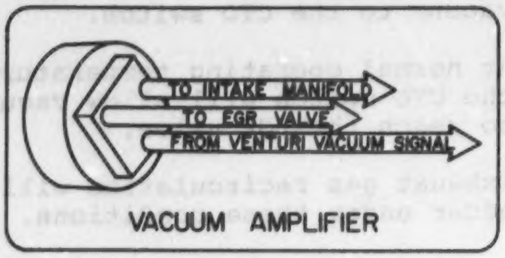

TO INTAKE MANIFOLD
TO EGR VALVE
FROM VENTURI VACUUM SIGNAL
VACUUM AMPLIFIER

Figure 8-4

C. Explain the operation of the Ported Vacuum EGR system with a CTO switch.

1. Low Engine Coolant Temperature Condition.

a) As the throttle is opened, a port is uncovered that allows vacuum to the CTO switch.

b) Below a specified coolant temperature the CTO switch prevents vacuum from reaching the EGR valve.

c) If no vacuum reaches the EGR valve no exhaust gas recirculation can occur.

d) This improves the driveability of a cold engine.

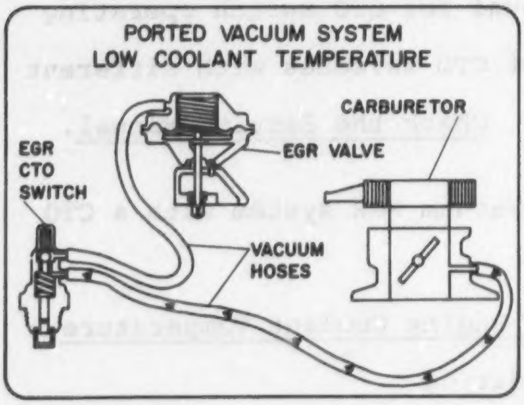

PORTED VACUUM SYSTEM
LOW COOLANT TEMPERATURE
CARBURETOR
EGR VALVE
EGR CTO SWITCH
VACUUM HOSES

Figure 8-5

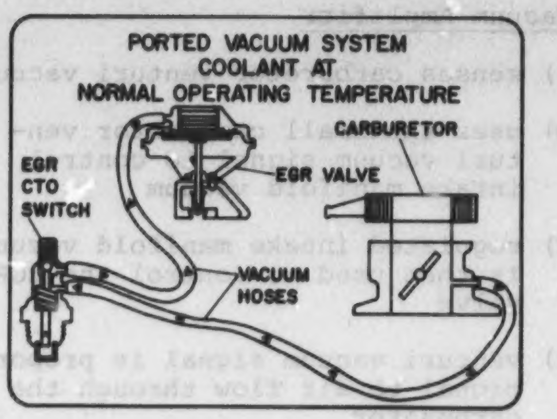

PORTED VACUUM SYSTEM
COOLANT AT
NORMAL OPERATING TEMPERATURE
CARBURETOR
EGR
CTO
SWITCH
EGR VALVE
VACUUM
HOSES

Figure 8-6

2. Normal Engine Coolant Temperature Condition.

   a) As the throttle is opened, a port is uncovered that allows vacuum to the CTO switch.

   b) At normal operating temperature the CTO switch will allow vacuum to reach the EGR valve.

   c) Exhaust gas recirculation will occur under these conditions.

NO exhaust gas recirculation occurs at full throttle. Intake manifold vacuum drops to value that is too small to hold open the EGR valve.

NOTE: Explain to students at this time the necessity for checking the manufacturer's service manual for CTO switch operating temperatures. A large number of CTO switches with different temperature settings are used. Check the Service Manual.

D. Explain the operation of the Venturi Vacuum EGR system with a CTO switch.

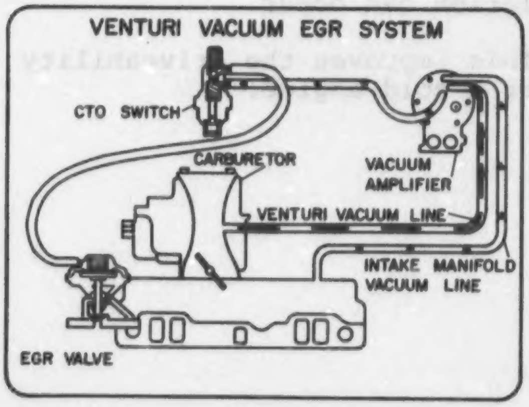

VENTURI VACUUM EGR SYSTEM
CTO SWITCH
CARBURETOR
VACUUM
AMPLIFIER
VENTURI VACUUM LINE
INTAKE MANIFOLD
VACUUM LINE
EGR VALVE

Figure 8-7

1. Low Engine Coolant Temperature Condition

   a) As the throttle is opened and engine speed increases, a venturi vacuum signal is generated by the increased air flow.

   b) The venturi vacuum signal is measured in the vacuum amplifier and a proportional amount of intake manifold vacuum is allowed to pass through the amplifier to the CTO switch.

   c) Below a specified coolant temperature, the CTO switch prevents vacuum from reaching the EGR valve.

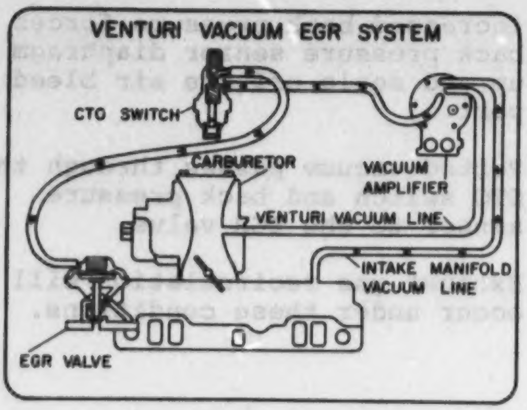

VENTURI VACUUM EGR SYSTEM
CTO SWITCH
CARBURETOR
VACUUM AMPLIFIER
VENTURI VACUUM LINE
INTAKE MANIFOLD VACUUM LINE
EGR VALVE

Figure 8-8

d) No exhaust gas recirculation is allowed and cold engine driveability is thereby improved.

2. Normal Engine Coolant Temperature Condition

   a) As the throttle is opened and engine speed increases, a venturi vacuum signal is generated by the increased air flow.

   b) The venturi vacuum signal is measured in the vacuum amplifier and a proportional amount of intake manifold vacuum is allowed.

   c) At normal operating temperatures vacuum is allowed through the CTO switch to the EGR valve.

   d) Exhaust gas recirculation will occur under these conditions.

E. Explain the Operation of the Ported Vacuum EGR system with the Back Pressure Sensor.

NOTE: This system also uses a CTO switch. The function is the same, vacuum is denied at low coolant temperature and allowed above a specified temperature. Explain to the student the following descriptions at normal operating temperature.

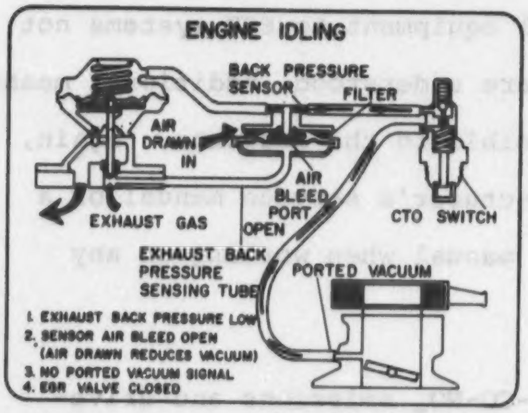

ENGINE IDLING
BACK PRESSURE SENSOR
FILTER
AIR DRAWN IN
AIR BLEED PORT OPEN
EXHAUST GAS
CTO SWITCH
EXHAUST BACK PRESSURE SENSING TUBE
PORTED VACUUM
1. EXHAUST BACK PRESSURE LOW
2. SENSOR AIR BLEED OPEN (AIR DRAWN REDUCES VACUUM)
3. NO PORTED VACUUM SIGNAL
4. EGR VALVE CLOSED

Figure 8-9

1. Engine running at idle or very low speeds.

   a) Exhaust back pressure is very low.

   b) Low back pressure allows spring to push down diaphragm in sensor.

   c) Air is allowed to be drawn into sensor and vacuum lines destroying any vacuum taht is present.

   d) No vacuum gets to the EGR valve and no exhaust gas recirculation occurs.

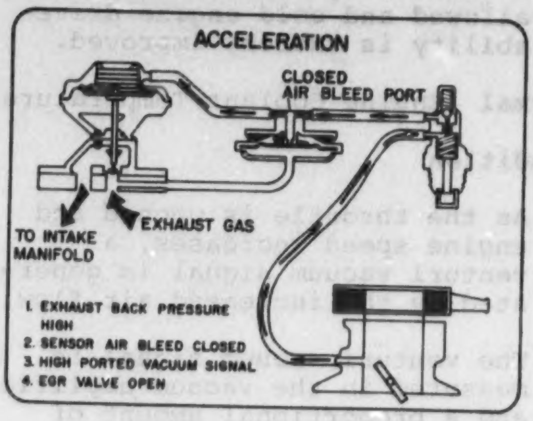

ACCELERATION
CLOSED
AIR BLEED PORT
TO INTAKE
MANIFOLD
EXHAUST GAS
1. EXHAUST BACK PRESSURE HIGH
2. SENSOR AIR BLEED CLOSED
3. HIGH PORTED VACUUM SIGNAL
4. EGR VALVE OPEN

Figure 8-10

2. Acceleration

a) Exhaust back pressure increases during acceleration.

b) Increased back pressure forces back pressure sensor diaphragm up and seals off the air bleed port.

c) Ported vacuum passes through the CTO switch and back pressure sensor to the EGR valve.

d) Exhaust gas recirculation will occur under these conditions.

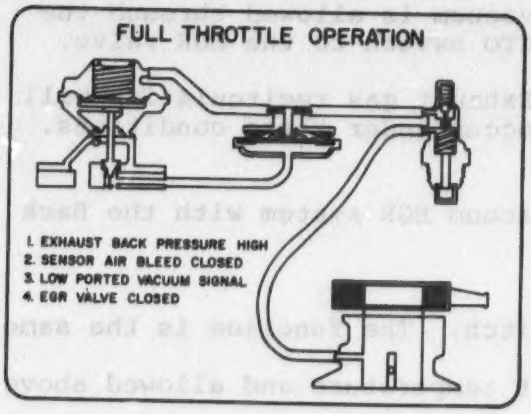

FULL THROTTLE OPERATION
1. EXHAUST BACK PRESSURE HIGH
2. SENSOR AIR BLEED CLOSED
3. LOW PORTED VACUUM SIGNAL
4. EGR VALVE CLOSED

Figure 8-11

3. Wide Open Throttle Operation

a) Exhaust back pressure is very high during acceleration.

b) High back pressure forces the sensor diaphragm up closing off the air bleed port.

c) During full throttle operation ported vacuum is too low to operate EGR valve.

d) The EGR valve remains closed under these conditions and no exhaust gas recirculation occurs.

NOTE: The EGR systems just covered are basic systems. Many manufacturers have added additional equipment to EGR systems not shown here. If these systems are understood, additional means of control should be comprehensible to the students. Again, encourage the use of the manufacturer's service manual or a good emissions control service manual when working on any system.

F. Explain how the EGR system affects HC-CO-NO_x emissions and driveability.

NO_x is not normally measured at an automotive service facility. NO_x analyzers are very expensive and not normally found in reapir stations. NO_x is controlled within federal limits if the EGR system is operating as it was designed to operate. Failure of EGR system components can cause hydrocarbon readings to be high at idle. Failures can also cause low speed driveability problems.

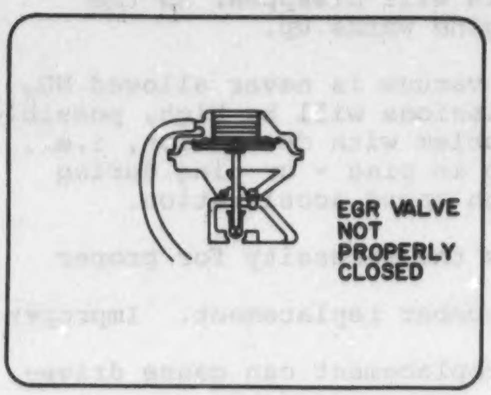


Figure 8-12

1. EGR valve that does not close properly
   a) exhaust gas allowed into the intake manifold at idle
   b) HC emissions may increase due to misfiring of cylinders caused by excessive dilution at idle
   c) excessive dilution at idle can cause a rough idle condition due to misfiring
   d) can cause rough off-idle acceleration problems due to exhaust dilution.
2. Conditions that can cause the EGR valve to open too soon or not close completely
   a) malfunction EGR system vacuum amplifier
   b) malfunctioning back pressure sensor with the wrong part number
   c) improper idle speed adjustment that allows EGR vacuum port to be uncovered at idle
   d) EGR valve replacement that is a wrong part number
   e) carbon buildup on valve or valve seat

3. Leaking EGR valve to base gasket

This allows exhaust gases to pass into intake manifold without going through the valve.

4. CTO switch failure

   a) If vacuum is allowed when the engine is cold a cold driveability problem will result. This will disappear as the engine warms up.

   b) If vacuum is never allowed NO_x emissions will be high, possible problem with detonation, i.e., tip in ping - or ping during high speed acceleration.

Stress the necessity for proper part number replacement. Improper part replacement can cause driveability problems as well as excessive emissions. Stress the use of VACUUM CIRCUIT DIAGRAMS and visual inspection of all vacuum bases for kinks, cracks, splits, looseness and excessive hardness.

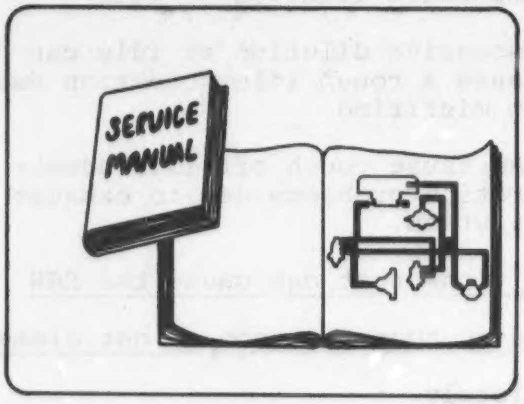


Figure 8-13

G. EGR System Operational Checks

Note: Insure area is well ventilated before performing these checks.

1. EGR Valve Operational Check

   a) Start engine and allow it to come to operating temperature.

   b) Disconnect the vacuum line at the EGR valve.

   c) Connect a hand pump to the EGR valve and apply 8-16" of vacuum.

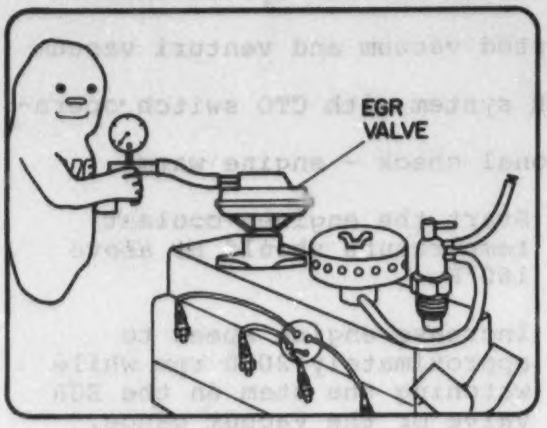


Figure 8-14

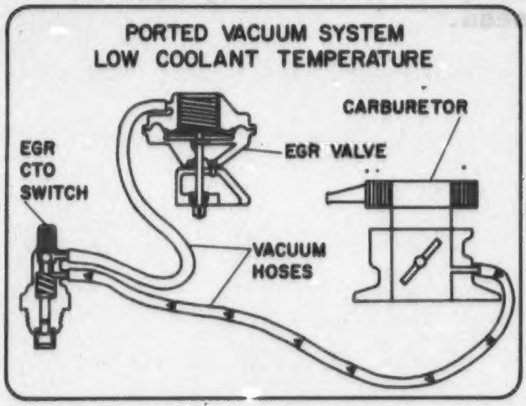

PORTED VACUUM SYSTEM
LOW COOLANT TEMPERATURE
CARBURETOR
EGR
CTO
SWITCH
EGR VALVE
VACUUM
HOSES

Figure 8-15

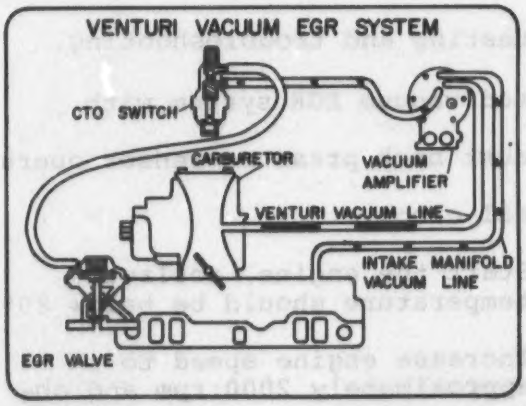

VENTURI VACUUM EGR SYSTEM
CTO SWITCH
CARBURETOR
VACUUM
AMPLIFIER
VENTURI VACUUM LINE
INTAKE MANIFOLD
VACUUM LINE
EGR VALVE

Figure 8-16

d) The engine should begin to idle roughly and possibly stall. The engine should smooth out when vacuum is removed from the EGR valve.

e) If the EGR valve does not open when vacuum is applied to it, replace the EGR valve.

NOTE: Most manufacturers recommend removing and inspecting the EGR valve at the following intervals.
1) every 12,000 miles if leaded gasoline is used.
2) every 25,000 miles if unleaded gasoline is used.

If this maintenance is not performed carbon and/or lead deposits build up around the valve seat and valve. These deposits could prevent the valve from closing completely or keep it from opening.

2. Ported vacuum and venturi vacuum

EGR system with CTO switch.

Operational check - engine cold.

a) Start engine, coolant temperature should be below 80°F.

b) Increase engine speed to approximately 2000 rpm while watching the stem on the EGR valve.

c) The stem should not move while the engine is cold.

d) If the stem on the EGR valve does move with the engine cold, the CTO switch is defective.

NOTE: If EGR valve stem is not visible, tee a vacuum gauge into the vacuum line to the EGR valve. Check for vacuum signal rather than stem movement. This applies to all EGR system checks.

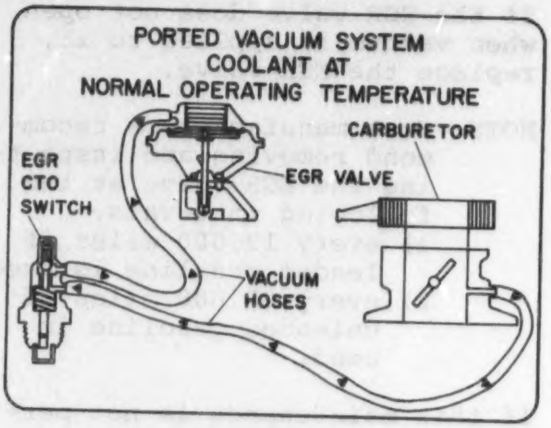

PORTED VACUUM SYSTEM
COOLANT AT
NORMAL OPERATING TEMPERATURE
CARBURETOR
EGR
CTO
SWITCH
EGR VALVE
VACUUM
HOSES

Figure 8-17

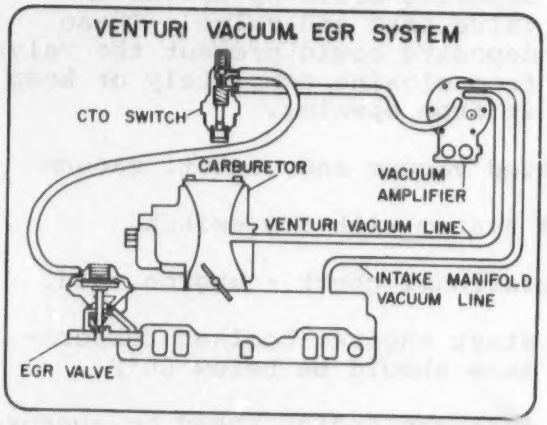

VENTURI VACUUM EGR SYSTEM
CTO SWITCH
CARBURETOR
VACUUM
AMPLIFIER
VENTURI VACUUM LINE
INTAKE MANIFOLD
VACUUM LINE
EGR VALVE

Figure 8-18

3. Ported vacuum and venturi vacuum EGR system with CTO switch operational check - engine warm.

   a) Start the engine, coolant temperature should be above 160°F.

   b) Increase engine speed to approximately 2000 rpm while watching the stem on the EGR valve or the vacuum gauge.

   c) The stem should move with the engine at operating temperature or a vacuum reading will be seen.

NOTE: These procedures are basic. Consult the manufacturer's service manual for exact procedures for testing and troubleshooting.

4. Ported vacuum EGR system with exhaust back pressure sensor operational check.

   a) Start the engine, coolant temperature should be below 80°F.

   b) Increase engine speed to approximately 2000 rpm and observe the vacuum gauge or the EGR valve stem.

c) The valve stem should not move and/or the vacuum gauge should read 0" Hg.

NOTE: It may be necessary to partially restrict exhaust flow to insure back pressure sensor receives an adequate pressure signal.

d) Let the engine warm up to operating temperature.

e) Increase speed to 2000 rpm and observe EGR valve stem or vacuum gauge. At operating temperature the EGR valve should begin to open.

f) It may be necessary to partially restrict exhaust flow to insure the back pressure sensor receives an adequate pressure signal.

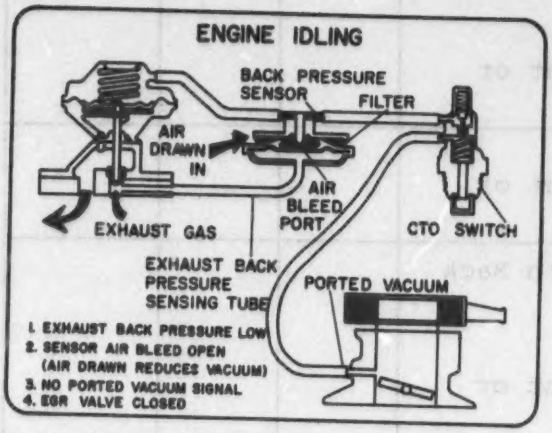

ENGINE IDLING
BACK PRESSURE SENSOR
FILTER
AIR DRAWN IN
AIR BLEED PORT
EXHAUST GAS
CTO SWITCH
EXHAUST BACK PRESSURE SENSING TUBE
PORTED VACUUM
1. EXHAUST BACK PRESSURE LOW
2. SENSOR AIR BLEED OPEN (AIR DRAWN REDUCES VACUUM)
3. NO PORTED VACUUM SIGNAL
4. EGR VALVE CLOSED

Figure 8-19

NOTE: Cars with single exhaust systems use a different back pressure than cars with a dual exhaust system. Be sure the one you are going to install is the proper sensor. If a dual exhaust sensor is used on a car with a single exhaust system this will cause a driveability problem.

A dual exhaust sensor operates at a lower back pressure. If this sensor is used on a vehicle with a single exhaust system it will result in too much exhaust gas recirculation. This will cause a large drop in engine power and fuel economy.

Have the students fill out the following worksheet in the student's workbook as they perform the tests.

Engine Speed	Test Conditions	Pass	Fail	Vacuum Reading
	EGR VALVE OPERATIONAL CHECK			
Idle				
2000 rpm	Ported Vacuum or Venturi Vacuum EGR Systems Engine Cold Check EGR valve stem movement or vacuum to EGR valve			
2000 rpm	Engine Warm Check EGR valve stem movement or vacuum to EGR valve			
2000 rpm	Ported Vacuum EGR System with Back Pressure Sensor Engine Cold Check for valve stem movement or vacuum to EGR valve			
2000 rpm	Engine Warm Check EGR valve stem movement or vacuum to EGR valve			

UNIT 9

SPARK CONTROL SYSTEMS

- BACKGROUND INFORMATION -

Spark control systems, or the control of ignition timing, have been around since the late 1960's. The purpose of spark control systems is to control the advance or retard of ignition timing. Controlling timing in this manner improves combustion and reduces the amount of NO_x and hydrocarbons emissions from the engine.

The majority of spark controls control the vacuum to the vacuum advance unit. This is the primary means of spark control today.

A. Explain the purpose for retarded spark timing at idle.

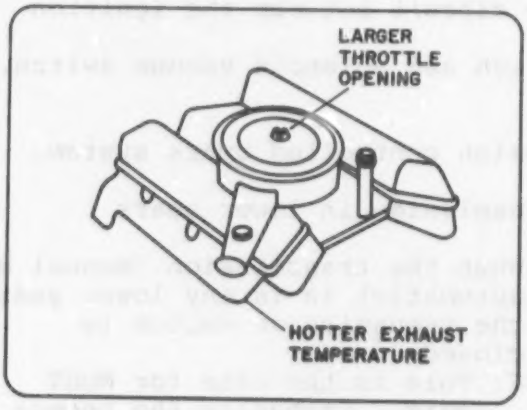


Figure 9-1

1. Retarding timing at idle causes
   - a) Engine speed to slow down.
   - b) Throttle plates must be opened further to bring engine rpm up to manufacturer's specifications.
   - c) Larger throttle opening allows more air to enter the engine, i.e., leaner air/fuel ratio. This reduces HC emissions.
   - d) Since ignition is taking place closer to TOP dead center, the temperature of the exhaust leaving the engine is hotter.
   - e) Hotter exhaust temperatures plus the leaner air/fuel ratio allows some burning to occur in the exhaust system. This also reduces HC emissions.

B. Identify the parts of a typical Transmission Control Spark System.

1. Carburetor - Provides a timed source of vacuum for the vacuum advance unit. (Vacuum port

normally located above throttle plates. No vacuum signal until throttle is opened.)

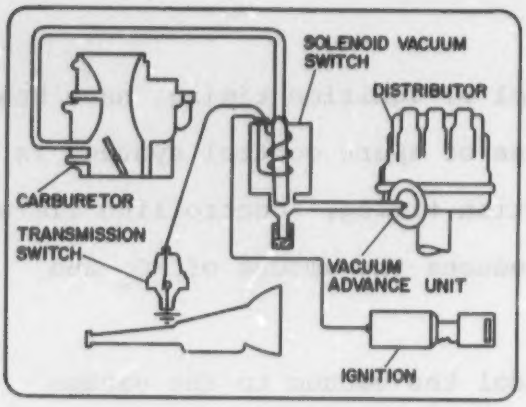

SOLENOID VACUUM SWITCH
DISTRIBUTOR
CARBURETOR
TRANSMISSION SWITCH
VACUUM ADVANCE UNIT
IGNITION

Figure 9-2

2. Vacuum Advance Unit - Advances ignition timing for maximum economy during cruising conditions. This is accomplished by a vacuum signal.
3. Solenoid Vacuum Switch - Prevents or allows vacuum to reach the vacuum advance unit.
4. Transmission Switch - Controls the solenoid vacuum switch. This is accomplished by amking or breaking the circuit between the ignition switch and solenoid vacuum switch.

C. Explain the operation of the transmission controlled spark system.

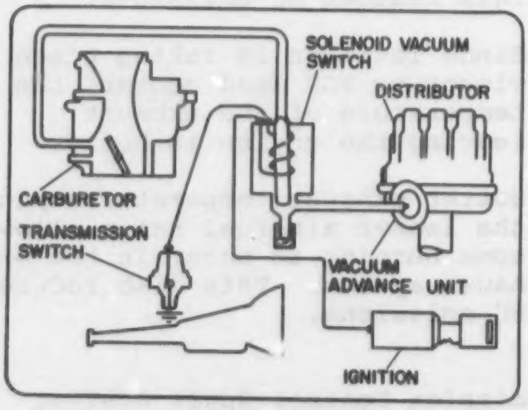

SOLENOID VACUUM SWITCH
DISTRIBUTOR
CARBURETOR
TRANSMISSION SWITCH
VACUUM ADVANCE UNIT
IGNITION

Figure 9-3

1. Transmission in lower gears
   - a) When the transmission (manual or automatic) is in any lower gear the transmission switch is closed.

     NOTE: This is the case for MOST cars. Emphasize the necessity for checking the manufacturer's service manual for exact specifications and settings.
   - b) With the transmission switch closed, the circuit is completed and the solenoid vacuum switch is energized.
   - c) When the solenoid vacuum switch is energized vacuum is prevented from reaching the vacuum advance unit.
   - d) Vacuum advance is denied.

2. Transmission in high gear.
   a) When the transmission is in high gear, the transmission switch opens.
   b) When the transmission switch opens, the circuit to the solenoid vacuum switch is broken.
   c) With the circuit broken, the solenoid vacuum switch is de-energized and vacuum is allowed to reach the vacuum advance unit.
   d) The vacuum advance unit now allows normal vacuum advance to occur.

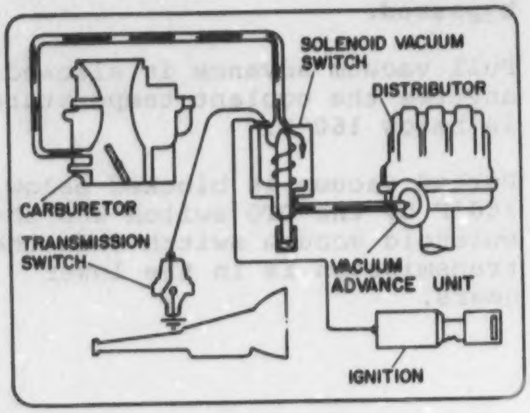


Figure 9-4

NOTE: Solenoid vacuum switches may be activated by governor oil pressure. If this arrangement is used, the system operates according to vehicle speed rather than gear selection. One manufacturer used a small generator in the speedometer cable. The generator put out a voltage proportional to vehicle speed. The generator signal ctonrolled the solenoid vacuum switch. Emphasize the necessity for checking the manufacturer's service manual or a good emissions control manual BEFORE working on these systems.

D. Explain the operation of a transmission controlled spark system with a coolant temperature (CTO) override switch.

Vacuum advance is allowed at low coolant temperatures on some vehicles. Allowing vacuum advance improves cold driveability.

1. When coolant temperature is below approximately 160°F
   a) The CTO switch allows manifold vacuum (below the throttle plates) to pass directly to the vacuum advance unit.

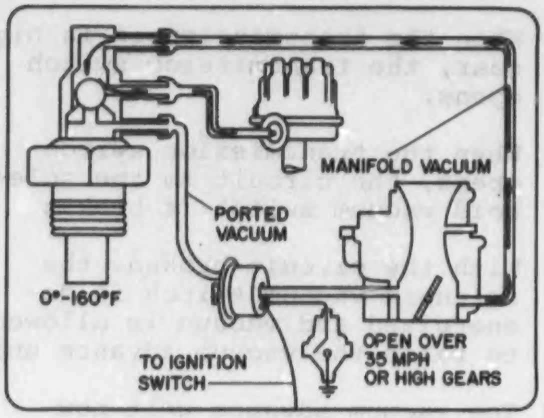

MANIFOLD VACUUM
PORTED VACUUM
0°-160°F
TO IGNITION SWITCH
OPEN OVER 35 MPH OR HIGH GEARS

Figure 9-5

b) The solenoid vacuum switch is bypassed.

c) Full vacuum advance is allowed anytime the coolant temperature is below 160°F.

d) Ported vacuum is blocked below 160°F by the CTO switch and the solenoid vacuum switch when the transmission is in the lower gears.

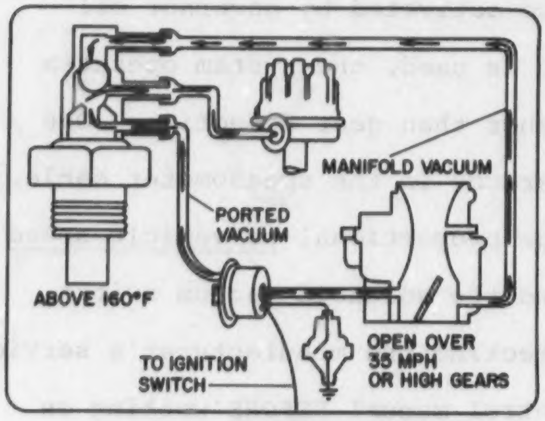

MANIFOLD VACUUM
PORTED VACUUM
ABOVE 160°F
TO IGNITION SWITCH
OPEN OVER 35 MPH OR HIGH GEARS

Figure 9-6

2. When coolant temperature is above approximately 160°F

a) The CTO switch blocks manifold vacuum to the vacuum advance unit.

b) Ported vacuum is allowed to pass through the CTO switch anytime the vehicle is in high gear.

c) In high gear the solenoid vacuum valve is de-energized and allows vacuum to pass to the vacuum advance unit.

E. Explain the operation of a transmission controlled spark system with hot and cold coolant temperature override switches.

NOTE: The solenoid vacuum valve is omitted from the firts two figures for simplicity.

1. Coolant temperature above approximately 160°F.

a) Ported vacuum from the carburetor first goes to the hot override switch.

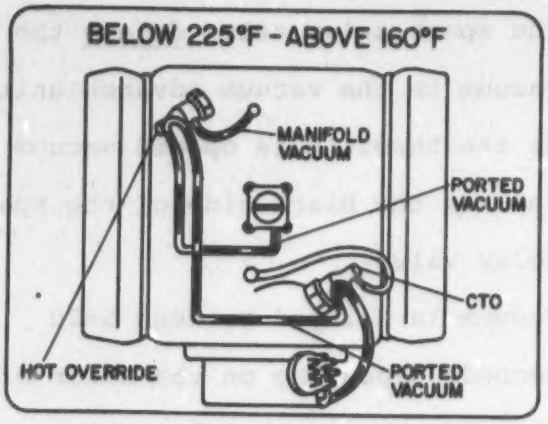

BELOW 225°F - ABOVE 160°F
MANIFOLD VACUUM
PORTED VACUUM
CTO
HOT OVERRIDE
PORTED VACUUM

Figure 9-7

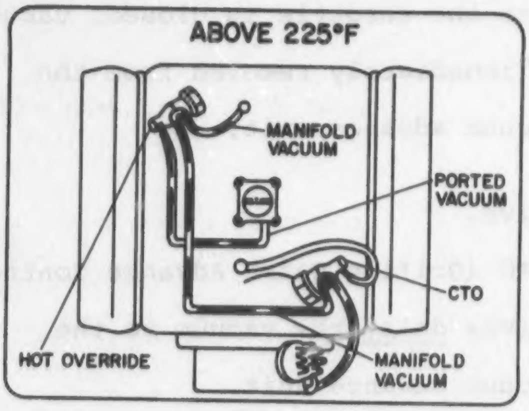

ABOVE 225°F
MANIFOLD VACUUM
PORTED VACUUM
CTO
HOT OVERRIDE
MANIFOLD VACUUM

Figure 9-8

b) If coolant temperature is below approximately 225°F, ported vacuum passes through the hot override switch to the CTO switch.

c) Above 160°F coolant temperature ported vacuum is allowed to the vacuum advance unit.

2. Coolant temperature above approximately 225°F

    a) Above 225°F the hot override switch blocks ported vacuum.

    b) Manifold vacuum is allowed to pass through the hot override switch to the CTO switch.

    c) Manifold vacuum passes through the CTO switch to the vacuum advance unit.

    d) The added spark advance increases engine speed, which increases fan speed and coolant flow to lower coolant temperature.

    e) Figure 9-9 shows the ssysem with the solenoid vacuum valve in place.

        1) The solenoid vacuum valve allows or denies ported vacuum depending on which gear the transmission is in.

        2) During a hot override condition, manifold vacuum bypasses the solenoid vacuum valve.

F. Explain the operation of the spark delay valve.

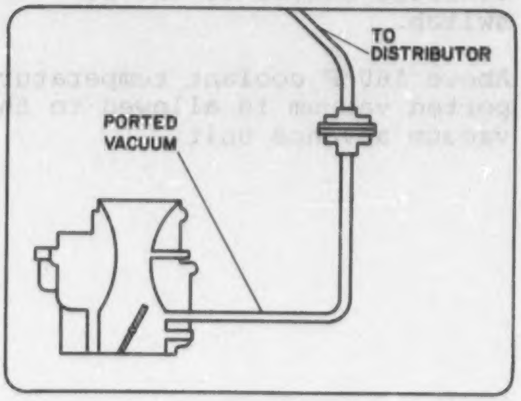


Figure 9-9

1. The spark delay valve delays the vacuum to the vacuum advance unit.
2. As the throttle is opened vacuum reaches the black side of the spark delay valve.
3. Vacuum is delayed between 5-20 seconds depending on the color of the side the spark delay valve facing the vacuum advance unit.
4. When the throttle is closed, vacuum is immediately removed from the vacuum advance unit.

G. Explain the operation of the OSAC valve.

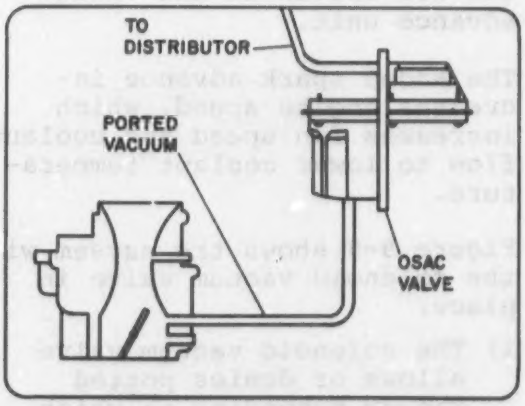


Figure 9-10

1. OSAC (Orifice Spark Advance Control) valves delay the vacuum to the vacuum advance unit.
2. As the throttle is opened vacuum reaches the lower side of the OSAC valve.
3. A delay of approximately 26 seconds is built into the OSAC valve. It takes this long for vacuum to equalize on both sides of the OSAC valve.
4. When the throttle is closed, vacuum is removed immediately from the vacuum advance unit.

5. Some OSAC valves permit vacuum to reach the vacuum advance unit immediately below 60°F. Above 60°F it takes approximately 26 seconds.

H. Explain how spark control systems can affect HC, CO and NO_x emissions and driveability.

1. Over advancing initial spark timing raises HC, CO and NO_x emissions.
   a) If timing is over advanced the throttle plates must be closed down to maintain special idle speed.
   b) This makes it very difficult to obtain low HC and CO levels and an acceptable idle.
   c) Advanced timing increases NO_x emissions because of higher peak flame temperatures during combustion.
2. Failure of transmission controlled spark system.
   a) If vacuum is allowed in the lower gears, excessive HC and NO_x emissions will result. There will be little appreciable gain in performance and fuel economy.
   b) If vacuum never reaches the vacuum advance unit, poor fuel economy will result.
3. Failure of CTO or hot override switch.
   a) If failure allows full manifold vacuum at all times high idle HC emissions levels will result.
   b) If failure allows only ported vacuum at all times, poor cold engine driveability will result.

4. Improper Spark Delay valve or OSAC valve operation.
   a) If vacuum is not delayed, higher levels of HC and NO_x emissions will results.
   b) If vacuum is completely blocked by these components, poor fuel economy will result.

Note: There are many variations in spark control systems. The concepts covered in this unit should allow other spark control systems and devices to be readily understood.

I. Spark Control Systems Operational Checks.

The operational checks suggested here will show whether or not the system or device is operating. It is strongly suggested that the proper manufacturer's service manual or a good emissions control manual be referred to for additional checks and specific procedures.

1. Transmission Controlled Spark system (Automatic Transmission).
   a) Tee a vacuum gauge into the vacuum advance line between the distributor and the solenoid vacuum switch.
   b) Start the engine and bring to operating temperature.
   c) Apply foot brake.
   d) Shift transmission selector to reverse.
   e) Increase engine speed to approximately 1500 rpm and observe vacuum gauge.
   f) A vacuum reading indicates the system is operational.

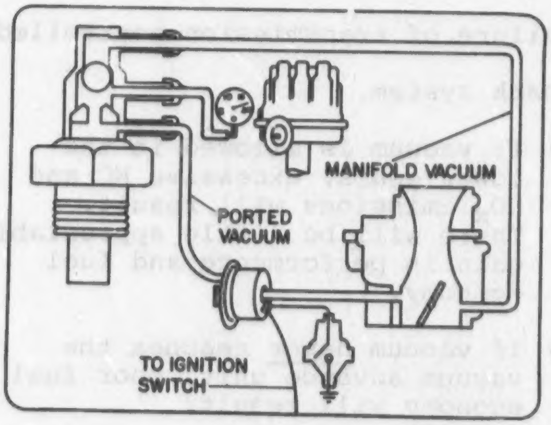


Figure 9-11

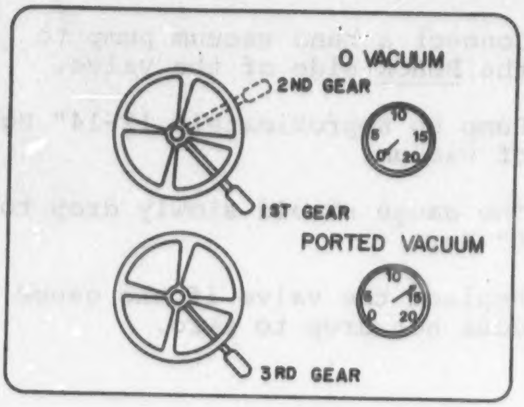


Figure 9-12

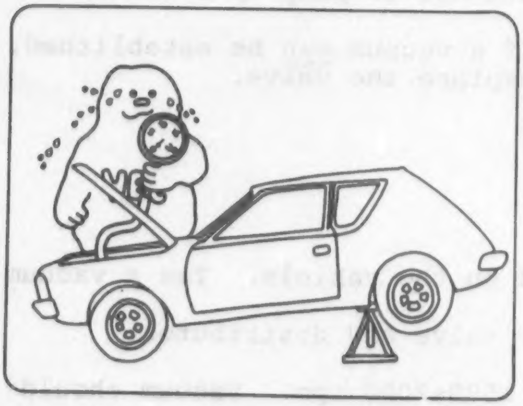


Figure 9-13

2. Transmission Controlled Spark (standard Transmission).

   a) Tee a vacuum gauge into the vacuum advance line between the distributor and the solenoid vacuum switch.

   b) Start the engine and bring to operating temperature.

   c) Depress the clutch, increase engine speed to approximately 1500 rpm and move the gear shift through the lower gears. No vacuum reading should occur.

   d) When the gear shift lever is put into high gear, a vacuum reading will indicate the system is operational.

3. Speed Controlled Spark System

   a) Tee a vacuum gauge into the vacuum line between the distributor and the solenoid vacuum switch.

   b) Raise both rear wheels and set jack stands.

   c) Start engine and warm to operating temperature.

   d) Shift transmission selector into DRIVE.

   e) Observe the vacuum gauge and slowly increase speed.

   f) A vacuum reading between 25-35 mph indicates the system is operational.

4. Spark Delay valve Operational Test

a) Remove spark delay valve.

b) Connect a hand vacuum pump to the BLACK side of the valve.

c) Pump up approximately 12-14" Hg. of vacuum.

d) The gauge should slowly drop to 0" Hg.

e) Replace the valve if the gauge does not drop to zero.

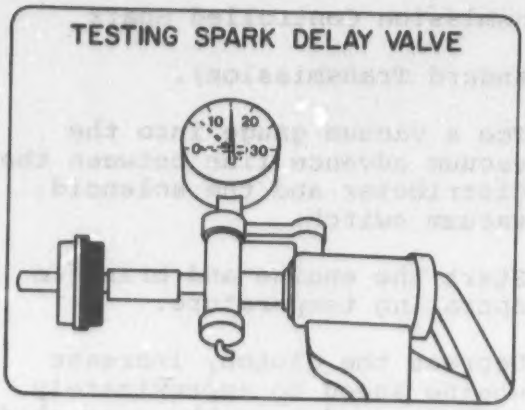


Figure 9-14

a) Connect a hand vacuum pump to the colored side of the valve.

b) Attempt to pump up a vacuum.

c) If a vacuum can be established, replace the valve.

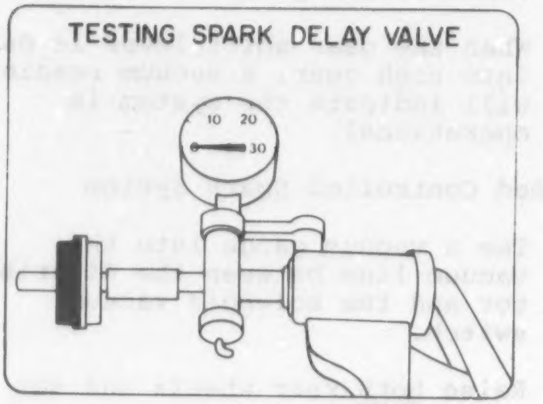


Figure 9-15

NOTE: Spark delay valves can be tested on the vehicle. Tee a vacuum gauge in between the spark delay valve and distributor. Increase speed to approximately 1500-2000 rpm. Vacuum should slowly increase and drop to zero when the throttle is closed.

5. OSAC Valve Operational Test.

a) Tee a vacuum gauge into the vacuum line between the OSAC valve and distributor.

b) Start engine and bring to operating temperature.

c) Increase engine speed to approximately 1500-2000 rpm.

d) If vacuum builds up to maximum in 15-25 seconds, and drops to zero when the throttle is closed OSAC valve is operational.

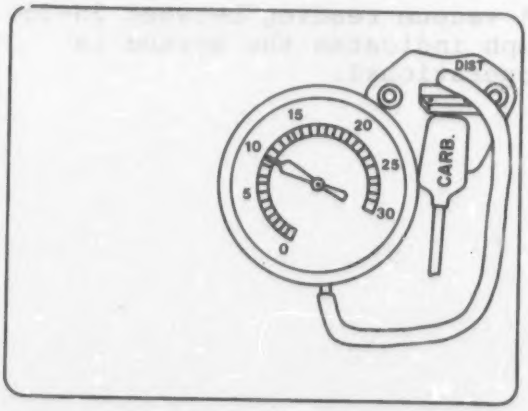


Figure 9-16

e) If no vacuum reading or a very low vacuum reading is present after 30 seconds, replace the valve.

Have the students fill out the following worksheet in the student's workbook as they perform the tests.

Engine Speed	Test Conditions	Pass	Fail	Vacuum Reading
TRANSMISSION CONTROLLED SPARK (AUTOMATIC)				
Approximately 1500 rpm	Engine at operating temperature Transmission selector in reverse			
TRANSMISSION CONTROLLED SPARK (STANDARD)				
Approximately 1500 rpm	Engine at operating temperature 1st gear (clutch depressed)			
	2nd gear (clutch depressed)			
	3rd or high gear (clutch depressed)			
SPEED CONTROLLED SPARK SYSTEM				
Slowly increase to 40 mph	Engine at operating temperature Rear wheels raised/jack stands Increase speed to approximately 40 mph			
SPARK DELAY VALVE				
Approximately 1500-2000 rpm or use hand pump				
OSAC VALVE				
1500-2000 rpm	Engine at operating temperature			
Throttle Closed				

UNIT 10

CATALYTIC CONVERTER SYSTEMS

- BACKGROUND INFORMATION -

The catalytic converter appeared on a majority of 1975 automobiles. The federal standards for HC and CO emissions that had to be met for 1975 and newer cars required the use of a very effective emissions control device. The catalytic converter's effectiveness in reducing HC and CO emissions prompted its introduction to meet these stricter standards.

The catalytic converter is placed in the exhaust system fairly close to the engine. The converter treats exhaust gases after they leave the engine. By treating the exhaust after it leaves the engine, the engine could be retuned for better performance and economy. The catalytic converter does not adversely affect the performance of the engine. However, the performance and tuning of the engine does affect the operation of the catalytic converter.

A. Explain the purpose of the catalytic converter.

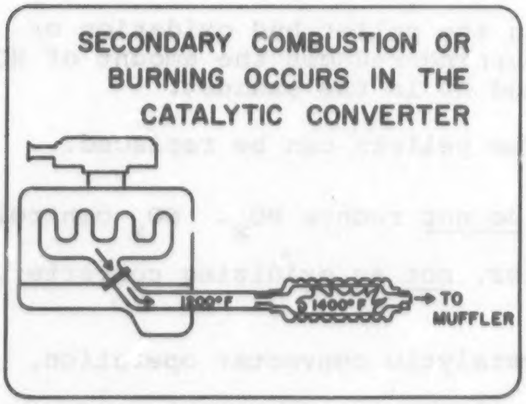


Figure 10-1

1. The catalytic converter performs the following functions.
    a) Provides a place where secondary burning of the exhaust gases can take place.
    b) Secondary burning allows for a more complete oxidation or burning of the exhaust gas.
    c) A complete oxidation or burning process results in large amounts of HC and CO being converted into water vapor (H_2O) and carbon dioxide (CO_2).
    d) HC and CO emissions are reduced to a very low value.

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B. Explain the construction of monolith and pellet type converters.

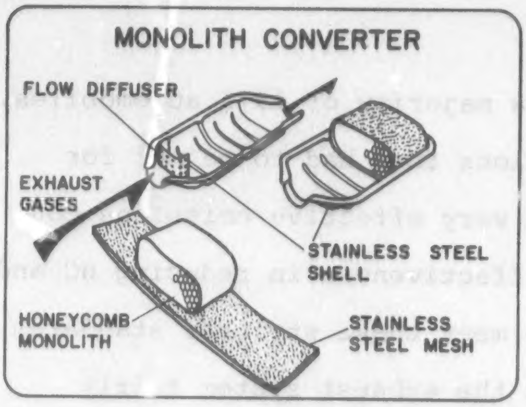
MONOLITH CONVERTER
FLOW DIFFUSER
EXHAUST GASES
STAINLESS STEEL SHELL
HONEYCOMB MONOLITH
STAINLESS STEEL MESH

Figure 10-2

1. Monolith converters
   - a) Can have one or two ceramic honey-combed monolith units in them.
   - b) The monolith units are cradled in a stainless steel mesh to protect them from road shocks.
   - c) Each monolith unit is covered with a thin coating of platinum or a platinum-palladium mixture. (These elements speed up the burning or oxidation process.)
   - d) Exhaust gas enters the converters, is spread out by the diffuser and flows through the honey-combed monoliths where the HC and CO are more completely burned.

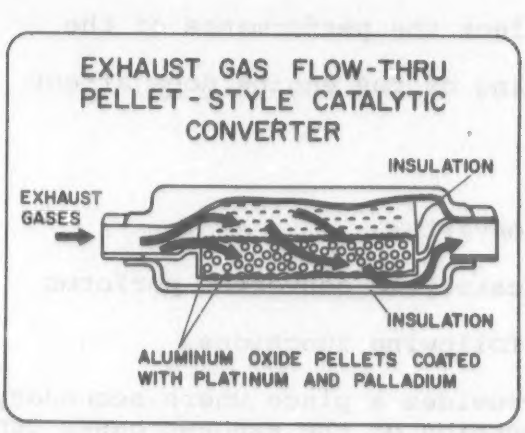
EXHAUST GAS FLOW-THRU PELLET-STYLE CATALYTIC CONVERTER
INSULATION
EXHAUST GASES
INSULATION
ALUMINUM OXIDE PELLETS COATED WITH PLATINUM AND PALLADIUM

Figure 10-3

2. Pellet type converters
   - a) Contains a bed of small aluminum oxide pellets that are coated with platinum or a combination of platinum-palladium.
   - b) Exhaust gases enter the converter and are directed downward through the coated pellet bed.
   - c) In the pellet bed oxidation or burning reduces the amount of HC and CO in the exhaust.
   - d) The pellets can be replaced.

Note: Oxidizing catalytic converters do not reduce NO$_x$. NO$_x$ control will require a reducing converter, not an oxidizing converter.

C. Explain how engine operation affects catalytic converter operation.

1. For burning to occur, oxygen must be present. Air, which contains oxygen, is supplied to the converter by:

a) The use of an air injection system

b) By excess air in the exhaust system which is determined by PROPER CARBURETOR ADJUSTMENT.

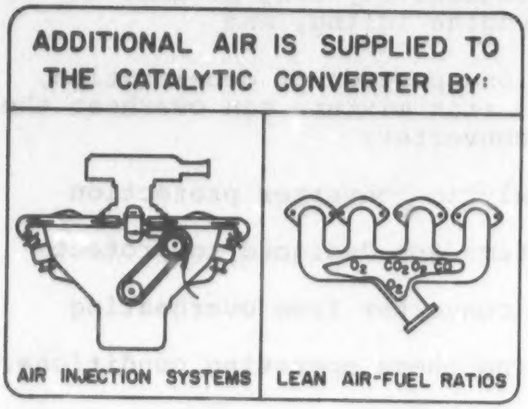
ADDITIONAL AIR IS SUPPLIED TO THE CATALYTIC CONVERTER BY:
O_2 CO_2 O_2 CO
O_2
AIR INJECTION SYSTEMS
LEAN AIR-FUEL RATIOS

Figure 10-4

NOTE: A common complaint with catalytic converters is the "Rotten Egg" odor. This odor results from not enough air being present in the exhaust system. A complaint odor can normally be cured by insuring the carburetor is properly adjusted for both idle speed and air/fuel mixture and/or by insuring the air injection system is working properly.

D. Explain the purpose for catalytic converter protection systems.

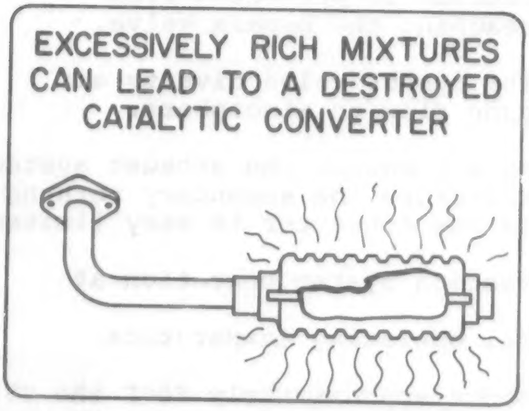
EXCESSIVELY RICH MIXTURES CAN LEAD TO A DESTROYED CATALYTIC CONVERTER

Figure 10-5

1. Catalytic converters provide a place for secondary burning of the exhaust gas.
2. The more unburned fuel (HC) that enters the converter, the hotter the secondary burning becomes. This is especially true of cars equipped with air injection systems.
3. During certain operating conditions, such as:
   a) cold starting (when the choke is applied),

b) excessively long periods of engine idling, and

c) long periods of deceleration, a rich mixture can overheat the converter.

4. Catalytic converter protection systems are designed to protect the converter from overheating during these operating conditions.

E. Explain the operation of a catalytic converter protection system.

Note: There are many different variations in protection systems. The following system is used only as an example. Consult the manufacturer's service manual before checking or servicing any catalyst protection system.

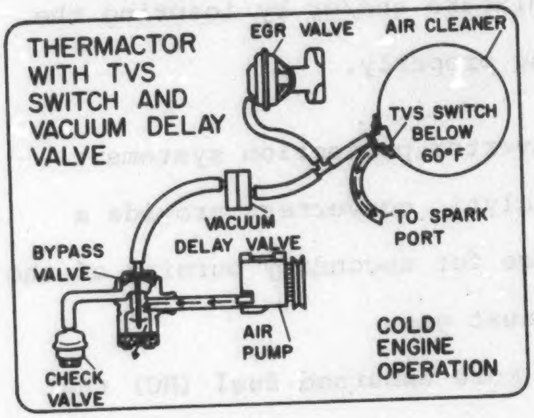
THERMACTOR WITH TVS SWITCH AND VACUUM DELAY VALVE
EGR VALVE
AIR CLEANER
TVS SWITCH BELOW 60°F
VACUUM DELAY VALVE
TO SPARK PORT
BYPASS VALVE
AIR PUMP
COLD ENGINE OPERATION
CHECK VALVE

Figure 10-6

1. Protection system operation when the engine is cold.
   a) Below approximately 60°F the TVS switch in the air cleaner is closed.
   b) Ported or spark port vacuum (only available when throttle is opened) is prevented from reaching the bypass valve.
   c) The bypass valve diverts air pump flow to atmosphere.
   d) No air enters the exhaust system, therefore the secondary burning in the converter is very limited.
2. Protection system operation at normal operating temperature.
   a) Above approximately 60°F the TVS switch in the air cleaner opens.

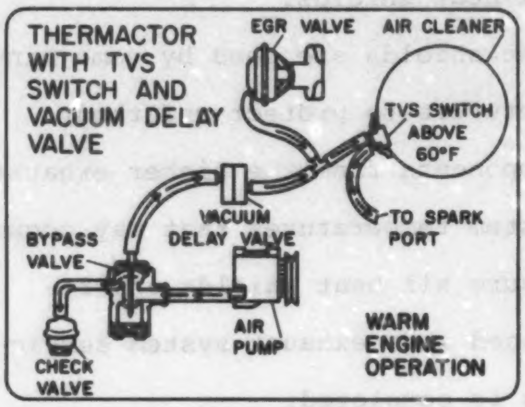
THERMACTOR WITH TVS SWITCH AND VACUUM DELAY VALVE
EGR VALVE
AIR CLEANER
TVS SWITCH ABOVE 60°F
VACUUM DELAY VALVE
TO SPARK PORT
BYPASS VALVE
AIR PUMP
CHECK VALVE
WARM ENGINE OPERATION

Figure 10-7

b) When the throttle is opened, vacuum is allowed through the TVS switch, through the vacuum delay valve to the bypass valve.

c) When vacuum is applied to the bypass valve, air pump flow enters the exhaust system.

d) The air entering the exhaust system provides additional oxygen to the catalytic converter and secondary burning occurs.

3. Protection system operation during extended idle or extended deceleration

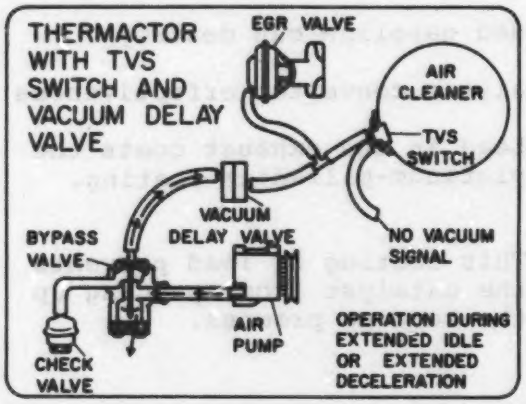
THERMACTOR WITH TVS SWITCH AND VACUUM DELAY VALVE
EGR VALVE
AIR CLEANER
TVS SWITCH
VACUUM DELAY VALVE
NO VACUUM SIGNAL
BYPASS VALVE
AIR PUMP
CHECK VALVE
OPERATION DURING EXTENDED IDLE OR EXTENDED DECELERATION

Figure 10-8

a) When the throttle is closed vacuum is destroyed in the vacuum line from the carburetor to the vacuum delay valve.

b) The vacuum delay valve prevents vacuum loss to the bypass valve for approximately 30-60 seconds.

c) During this 30-60 seconds, air pump flow is being directed to the exhaust system and secondary combustion is occuring in the catalytic converter.

d) After approximately 30-60 seconds, no vacuum remains at the bypass valve. The bypass valve dumps the air pump flow to atmosphere. No additional air is supplied to the exhaust system and secondary burning in the converter is very small.

Note: Misfiring spark plugs and execssively rich air/fuel mixtures can damage any catalytic converter. Limit tests that require spark plug shorting to the amount of time suggested by the manufacturer in the service manual.

F. Explain the purpose of exhaust system heat shields.

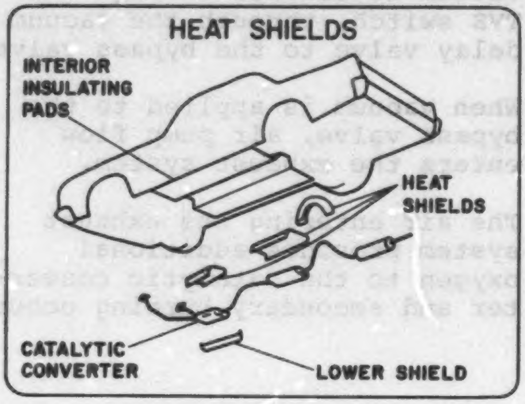
HEAT SHIELDS
INTERIOR INSULATING PADS
HEAT SHIELDS
CATALYTIC CONVERTER
LOWER SHIELD

Figure 10-9

1. Heat shields are used by some manufacturers to protect underbody components from the higher exhaust system temperatures that may occur.
2. Insure all heat shields are replaced when exhaust system servicing is completed.

G. Explain why unleaded fuel must be used in catalytic converter equipped cars.

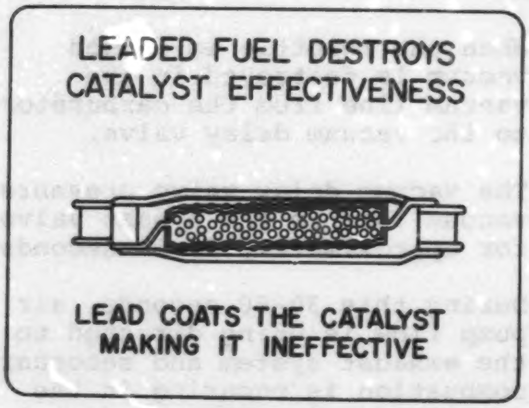
LEADED FUEL DESTROYS CATALYST EFFECTIVENESS
LEAD COATS THE CATALYST MAKING IT INEFFECTIVE

Figure 10-10

1. Leaded gasoline can destroy catalytic converter effectiveness
   - i) Lead in the exhaust coats the platinum-palladium coating.
   - ii) This coating of lead prevents the catalyst from speeding up the burning process.

H. Explain how catalytic converters can affect HC, CO and NO_x emissions and driveability.

1. Oxidizing catalytic converters do not have any effect on NO_x emissions.
2. Converters have no effect on driveability.

   c) Inspect catalytic converter for physical damage and overheating.

2. Operational Checks

   a) Warm up, zero and span an infrared exhaust analyzer.

   b) Start engine and bring to operating temperature.

   c) Probe the tailpipe and record HC-CO at idle.

   d) Increase speed to 2000 rpm and record HC-CO.

Note: If the catalytic converter is operating properly idle CO readings should be extremely low and HC readings should be approximately 20 -100 PPM. If readings are higher, (CO approximately 2-8%, HC 100-400 PPM) use the manufacturer's procedure for adjusting ignition timing and setting idle speed and idle air/fuel ratio. Follow the manufacturer's instructions for checking the air injection system and catalyst protection system.

Have the students fill out the following worksheet in the student workbook as they perform the tests

Engine Speed	Test Conditions	Pass	Fail	HC (ppm)	CO (%)
0	**VISUAL INSPECTION**				
	a) Catalytic Converter(s) b) AIR Pump c) Protection Systems d) Hose Condition e) Hose Connections f) Hose routing				
Idle	**OPERATIONAL CHECKS**				
	Tailpipe Analyzer Reading				
2000 rpm	Tailpipe Analyzer Reading				